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ABSTRACT

This project was directed towards exploring issues in undergraduate engineering education and presenting recommendations for future activities in engineering education at two universities. The report includes 14 recommendations pertaining to engineering education in areas such as: practical training, course structure and organization, teaching methods, assessment, staff development, and course development. Samples of instruments used in the study are included. (SL)

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Educational Objectives in Applied Science

Report to the Leverhulme Trust

SE021 673

D. J. Boud

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June 1976

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SYNOPSIS

Educational Objectives in Applied Science is a joint research project between the University of Strathclyde and Heriot-Watt University funded by the Leverhulme Trust from 1972 to 1976. The project was concerned with educational developments in the undergraduate courses in mechanical and civil engineering and computer science in the two universities.

The project focussed on the major issues in undergraduate engineering education as determined by staff and by students in the departments involved in the study and explored the aims and activities of the courses in the two universities.

Most of the outcomes of the project were directed towards facilitating changes in the courses that were involved and the results of these aspects of the work were reported directly to the staff involved. A final report has been prepared which discusses the development of the project, gives examples of the kinds of research and development that were undertaken, explores some issues in undergraduate engineering education and presents recommendations for future activities in engineering education at the two universities.

Copies of the full report to the Leverhulme Trust (120 pages) and a summary of that report are available from Miss Jean M. G. Hardie, Assistant Secretary, Royal College, University of Strathclyde, Glasgow G1, (041-552-4400 x 2240).

SUMMARY

AIMS

The Leverhulme Project on Educational Objectives in Applied Science started in 1972 with the purpose of assisting staff in the areas of mechanical and civil engineering and computer science to specify the aims and objectives of the undergraduate courses so that their teaching methods and assessment procedures might be reviewed in the light of them. A research fellow was appointed to co-ordinate these activities and enable the departments involved to pursue the programme.

The project proceeded in two phases. The first was conducted with Mr. W.T. Koc as research fellow and concentrated on the computer science area. The second phase, after Mr. Koc's resignation through ill health, focussed on mechanical engineering and, to a lesser extent, civil engineering, with Dr. D. J. Boud as research fellow. The final report concentrates particularly on the second phase of the project.

It was found that the commitment of staff in the departments to the task of specifying objectives for their courses was not great and that the project could be more effectively conducted by examining the undergraduate courses in situ than by an approach based on the use of objectives.

The project was originally formulated as one in which the researcher might be responsive to the needs of departments and much of the success of the involvement in the courses was due to respect for this principle.

ACTIVITIES

The main features of the second phase were :

(a) The production of portrayals of the undergraduate courses.

An extensive programme of interviews and group discussions with staff and students was conducted in order to assemble a critical portrayal of each undergraduate course as viewed by those people most immediately involved. The aim of these was to provide a basis for later, more detailed investigations of particular areas.

A confidential document for each course resulted and as a result of consultations with staff in each department plans were made for the next aspect of the study.

(b) The evaluation of development of particular aspects of the courses.

Although many problem areas were indicated it only proved possible for the project to be invited to work with those aspects of the courses that were currently or shortly to be undergoing change. Particular attention was given to the new first year engineering course at Strathclyde, Engineering 16.151, and to one of its innovative features, the skills tutorials.

Evaluations were undertaken of this and some other aspects of the undergraduate course and the project worked in close collaboration with the engineering staff to plan for change in response to the experience and formal evaluation of the courses.

(c) Surveys of the aims of the undergraduate curriculum.

In parallel with the specific investigations a survey was conducted amongst all staff and graduating students in mechanical engineering at Strathclyde and Heriot-Watt. They were asked to rate the extent to which certain aims were important in the undergraduate course, the extent to which the course was successful in pursuing these aims and to give more extensive comments about their experience of the course.

OUTCOMES

The aims survey provided a basis for comparison between the two courses and between the views of staff and students. It was found that there was a high degree of matching between the views of the two groups and that the two courses had similar profiles on this measure. The specific discrepancies pointed to areas of the courses which were seen to be underdeveloped and particular variations indicated some individual differences of detail between the two courses.

Much experience of the difficulties and possibilities of an externally supported project to facilitate educational development was gained. Of particular importance was the need that was determined for adequate support for innovation in undergraduate teaching. One of the most useful functions of the project was to give sympathetic, but critical, support for staff who were attempting to implement changes in the undergraduate course.

Various issues in undergraduate teaching that arose from the study are discussed in the final report. Two of the most important concern the role of professional and practical training in undergraduate engineering education and the development of students' independence or autonomy in learning.

Recommendations and proposals for further work are made. Whilst many of these are directed primarily to the departments concerned, others have a wider importance both within the universities and elsewhere.

Responsibility of University Departments in Professional Education

1. Engineering departments should consider attempting to define and clarify the boundaries of their responsibility with regard to the professional training of engineers in lieu of any national decision on this matter.

Role of Practical Training in Engineering

2. Engineering departments should consider examining and making explicit the demands that they would ideally and realistically make with regard to practical training for engineering students, before, during and after the period of the undergraduate course.

Structure and Organisation of the Undergraduate Course

3. Given the present departmental structure, departments contributing to an undergraduate course should consider structuring their teaching responsibility such that the course is planned and supervised as a single unit, rather than as an assembly of sub-units.

3.1 The day to day responsibility for the course to lie with a course co-ordinator, drawn from the staff of the department, who should be a person of high status and with particular interest and ability in undergraduate teaching.

3.2 The course co-ordinator to be supported by year co-ordinators who would be responsible for each year of the undergraduate course and have appropriate administrative and secretarial support.

3.3 The course and year co-ordinators would form a course team who would be responsible for overseeing the undergraduate curriculum and monitoring the progress of the course. They would have direct access to the School Board and be responsible for planning and implementing changes in the course in conjunction with the heads of participating departments and their staff. The course team members would be drawn from the participating departments, but their principal teaching and administrative load would be directed towards the undergraduate course.

3.4 The course team to be seen as a co-ordinating body. Course development should not be a centralised procedure. It must actively involve all contributing staff at all stages. A consultative procedure would not encourage a sufficient investment or commitment on the part of staff.

Teaching Methods

4. Consideration should be made of the introduction of teaching methods in undergraduate courses which encourage students' autonomy. Such methods could include : individual learning materials, small-group work, greater use of text-books and library facilities, case studies, and small scale project work.

Development of Communication Skills

5. More opportunities for the development of written and verbal communications skills should be considered for inclusion in the undergraduate course. Wherever possible this should be an integral part of engineering subjects and should not solely be developed in courses such as the Engineer in Industry and Society and special courses in communications. The effective development of these abilities requires both practice and feedback, and opportunities should be provided for both.

Assessment

6. Consideration should be made of broadening the range of aspects of courses that are assessed within the limits of the present syllabuses. This should be done to emphasise the importance of such skills as problem formulation and model building as well as those of analysis.

Staff-student Relations

7. In the long term staff-student relations can only be developed through greater participation and involvement of students in the courses and in course development and evaluation. Social activities are worthwhile, but are not a substitute for close contact in the teaching situation. In an unsuitable physical environment, such as the James Weir Building at the University of Stratnclyde, particular attempts to develop contact between staff and students should be considered.

Staff Development

8. It should be considered that staff be encouraged to broaden their interests in terms of teaching and in the social and industrial applications of the subjects they teach. Procedures for the low cost acquisition of experience by staff should be investigated. These could include the exchange of staff, the short term attachment of staff to institutions educational, industrial and public, for example, to observe and participate in new teaching practices. If these were undertaken for short periods then the disruption of teaching and research could be minimised and financial support could be arranged.

9. In particular it should be considered that staff be given the opportunity for attendance and participation in courses and workshops concerned with educational development. Attendance should be given similar standing to that at research conferences. Funds should be made available for this so that research and teaching do not compete at the departmental level.

10. The reward structure of the institution should give adequate incentive to teaching ability vis-a-vis research and it must be seen to provide such an incentive.

Course Development

11. Developments in teaching can be most easily and effectively conducted when there is active support, both from the highest level in departments and elsewhere, and from the level of grass roots staff. It is desirable that any proposal for an educational development be initiated jointly between senior staff and those most actively involved so that both parties have an active investment in it.

12. The time scale of educational developments is long and a planned scheme should preferably be monitored over at least three years before a decision on its acceptance or rejection is made. This time should be spent on modifications and changes to make improvements in the light of an on-going programme of course monitoring.

13. It is desirable that support be provided for educational innovation. At one level it should be in terms of money that is available from the normal teaching budget to aid worthwhile schemes. At another level some form of personal support for innovative staff is helpful. This can be provided in part by consultants outwith the departments who are knowledgeable and skilled in a variety of teaching methods and who have the personal skills required to aid, but not dominate, individual innovations. Such a consultant, or consultants, could most effectively be attached to any central university facility to aid teaching.

Continuing Investigation

14. It is desirable that courses be monitored to examine their effectiveness and also that longer term planning be undertaken to provide for needs which are not being met by present provisions. These should be regular on-going activities and be recognised as important in departmental planning.

15. Participating departments should consider the worth of specifying aims and objectives both for the overall undergraduate course and for individual courses. Clear reasons should be given for the acceptance or rejection of this proposal. If the proposal is accepted then the advice of internal and external consultants should be sought on the methods to be adopted and the resources required for such an activity.

16. An investigation into examinations should be considered to determine the aims of the present assessment system as presently constructed and to assess the degree of congruence between those educational objectives that are tested and those that it is desirable to develop in students.

17. Any investigation that is considered should be undertaken first of all at departmental level as a pilot study, in order to determine the degree of commitment of staff to the process before external funds are sought.

Introduction

The aim of this report is to review the activities of the project 'Educational Objectives in Applied Science', a joint venture between the University of Strathclyde and Heriot-Watt University from 1972 to 1976. It will describe the development of the project during this period and will focus in particular on the later stages from 1974 to 1976, when the writer held the post of Leverhulme Research Fellow.

Although the project was formally entitled 'Educational Objectives in Applied Science', the main thrust has not concentrated on the specification of objectives. During the period of the project a great deal of experience was assembled in the almost unexplored field of undergraduate engineering education and this report presents a distillation of this. It does not attempt to be a formal research account, rather an account of some of the findings written for the audience of university teachers not familiar with educational research terminology. The report puts forward some observations about engineering education and discusses these in the light of the particular situations to be found at Strathclyde and Heriot-Watt. Some of its findings are likely to be transferable to other contexts, but this report attends specifically to the problems of undergraduate engineering education in the two universities.

The project was first funded by the Leverhulme Trust in 1972, in response to a proposal from the two universities. The programme outlined envisaged that the project would assist departments of applied science

a) to determine the objectives for the education of applied scientists,
b) to examine the extent to which the undergraduate course was pursuing these objectives,
c) to help the departments assign priorities in the light of such a specification.

Mr. W. T. Koc was appointed as the first Leverhulme Research Fellow and during the first phase of the project pursued this programme with the Computer Science departments in each university. Mr. Koc was unfortunately forced to resign a year or so later through ill health but, since the universities felt the project sufficiently worthwhile and were endorsed in this by the Leverhulme Trust, a new appointment was made with a remit to develop the project principally with the remaining two disciplines that had been initially involved, that is, Mechanical and Civil Engineering. After a fallow period of approximately fifteen months a second phase was initiated with my appointment. The approach of the project was modified and the original programme adapted to meet the new situation.

In the light of the experience of the first phase a change of emphasis was considered desirable, more attention being focussed on the ongoing teaching programmes of the departments. This was in response to the observation that teaching staff had not taken readily to the objectives-based approach and had found that approach rather abstract and not clearly related to their teaching activity.

The original proposal had stressed that the role of the Research Fellow was to assist and enable departments to undertake the task of developing their teaching programmes. It was found that someone with this role was not immediately assimilable in the departments and that some negotiation of the specific activities of the project had to occur. Departments were not undertaking an examination of their teaching programmes in terms of defined objectives and faced with such a situation the project had to find a strategy that was compatible with the situation as it existed.

The programme that was eventually adopted by the writer concentrated mainly on the Mechanical Engineering departments. A study, based on extensive interviews with staff and students to examine the existing undergraduate course, was conducted in each department. This resulted in a portrayal of the course from the points of view of the various parties directly involved and was supplemented by direct observation of teaching situations. These portrayals acted as the stimulus for protracted discussions in the mechanical engineering departments and, out of these, activities for the final phase of the project were determined.

The final phase aimed to be entirely responsive to the needs of the collaborating departments. The main activity took the form of an evaluation of the newly-established first year engineering course at Strathclyde and,combined with that, support for and an evaluation of a particular innovation within that course, 'skills tutorials'. These will be discussed at greater length in Part II.

In parallel with these activities,and in response to the apparent low level of awareness of explicit aims and objectives in the departments, a survey of the aims of undergraduate mechanical engineering was conducted with staff and graduating students in the two universities. The effect of this survey and the responses to it were as instructive as the results and an account of aims and objectives and their role in undergraduate course development was produced.

This report does not aim to present a full account of the empirical studies that formed the basis of the project. These will be mentioned but not described in detail. Much of the information was accrued solely for the internal use of teaching staff to help them improve their own courses and, necessarily, a guarantee of confidentiality was undertaken with them. It is only under such circumstances that a climate of trust can be established to enable both staff and students to be completely frank about their teaching and learning experiences. In particular, some of the internal reports of the project quote opinions of staff and students within a department about the undergraduate course. Whilst some of these will be presented to illustrate the present report, this will not be in such a way that individual courses can be identified; if this were not so then remarks could prove grossly misleading. The very act of focussing on departments and reporting on some of their activities gives the impression that they are in some sense untypical. That some departments in the two universities agreed to participate in the project is a testament to their goodwill, openness and courage that others might benefit through sharing experience of some of their problems and innovations. The participating staff and departments should be acknowledged at this time : they have revealed themselves generously.

This report does not deal with all the activities of the project. It has aimed to do many things and some of these are not appropriately served by inclusion in a final report. One aim has been to give support and assistance to individual teachers who were concerned to improve their teaching and develop their own parts of the undergraduate course. The research fellow has engaged in individual consultations with staff on this basis, both within the engineering departments and in one of the service departments. In two cases that are not reported further this work has been followed with groups of staff working together on courses and has taken more public and substantive form in the evaluation of a second year Mechanics of Materials laboratory course, and in the evaluation of the third and fourth year course, 'the Engineer in Industry and Society' at Strathclyde. These were reported in the first case to a staff seminar and in the second in the form of a report, and a discussion meeting. The latter resulted in a working seminar with tutors to help improve the small group discussions which were an integral part of the course.

A workshop on Development of Mechanical Engineering Education was arranged for staff of the two universities and this was followed by an initiative by the Mechanics of Materials department at Strathclyde to set up a similar meeting with Professor Colin Page of the University of Bradford. In these ways staff were brought together to discuss common problems and share experience.

The presence of the project in the university has enabled contributions to be made to the induction and in-service training courses for new staff in the area of objectives in university teaching and in methods of small group teaching. In addition, in the area of small group teaching, three one-day or half-day workshops have been organised and staffed by the project for staff throughout Strathclyde University. The expertise of Mrs. M. L. J. Abercrombie and Professor Brigitte Eckstein has, through these, been brought to contribute to the wider training of staff in teaching methods. These activities have developed further with a workshop commissioned by the staff of Applied Microbiology to work on specific problems of laboratory work using small group techniques and with the possibility of the setting up of an on-going study group on these particular aspects of university teaching.

The remainder of the report is organised in three sections. Part I is devoted to the process of the project. It describes the activities that were initiated, the constraints that were found and the kind of work that was made possible. Part II is concerned with undergraduate engineering education and in particular to aims, drawing on the survey of aims of mechanical engineering education and presenting two case studies of elements of a new first year course in engineering at Strathclyde. Part III looks to the future and to some of the key issues that have been uncovered by the project. It examines the implications of a project of this nature in the university and presents some tentative recommendations, or hypotheses, for the future improvement of undergraduate engineering teaching.

PART ONE

THE ORIGINS AND DEVELOPMENT OF THE PROJECT

THE ORIGINS AND DEVELOPMENT OF THE PROJECT

This section aims to chronicle the changing nature of the project since its conception and to highlight some of the crucial decisions that influenced the path and nature of the work. The description will concentrate on the processes of the project, about its methods of working and on the constraints that were faced. The substantive outcomes will be presented in Part II.

The barest outline has been reviewed in the Introduction. The various stages will be discussed at greater length to examine two questions. The first question that will be addressed is : what did the project do ? The second question is : who was the project for ? It will be clear that various audiences had rather different, and sometimes, conflicting expectations. The main activities will be described and placed in the context of the expectations of the interested parties and the assumptions underlying the nature of the activities that were pursued will be discussed.

Background

The idea for a project on educational objectives originated in a report on 'Methods of Academic Assessment' presented to the Senate of the University of Strathclyde in June 1969. A year earlier a working party had been set up to consider the methods of assessment available and in use at Strathclyde at that time and to make recommendations to the Senate for developments in this field which it considered desirable. One of the main views of the working party was "that the defining of course objectives is an indispensable part of the whole assessment problem". They realised that it was not a task that could be "lightly undertaken by academic staff qualified in only one discipline, however sincere their efforts" and that academic staff required some assistance in pursuing this task.

The working party proposed that the university should initiate an experimental pilot study into the defining of course objectives and that they enlist the aid of a body outwith the university and expert in the field of research into higher education. "The type of experiment envisaged would involve close co-operation between the investigating unit and three volunteer departments representative of the University's work and would be concerned in assisting them to reach their own definitions of course objectives and matching their methods of assessment to those objectives. We hope and expect that the 'educational fall-out' on other sections of the staff would be considerable and expertise in the technique could be gained by many more members of the teaching staff than were actually involved in the experiment. We believe that every encouragement should be given to departments to start their own self-examination."

This recommendation was accepted by the Senate and a group chaired by the then Vice-Principal, was convened to implement it. After some consideration it was found that a project concentrating on the field of applied science and involving another university could be financed. Heriot-Watt University, the other technological university in Scotland, was approached and their support enlisted. A joint proposal was submitted by the two universities to the Leverhulme Trust in Spring 1971. Three disciplines of each university had agreed to take part : Computer Science, Mechanical and Civil Engineering, although at that time it was not clear what commitment each had to the practice of the specification of educational objectives. These departments were not selected on the basis of their previous involvement in the defining of objectives, nor were they asked to give a detailed commitment of time and resources to the project.

It was proposed that "the main activities of the project will be carried out by members of the departments mentioned, and their commitment in terms of time will be considerable". It was also proposed that their efforts be co-ordinated by a research fellow appointed from outside the two institutions, and that an external consultant be appointed to give additional support. The specific objectives of the research were defined as follows :

(i) To enable departments in applied science to determine the qualities or qualifications which a successful student should possess at the end of his course, in terms of :
  a) Knowledge
  b) Skills
  c) Orientation and attitudes

  with due regard to the ultimate qualifications required of the professional man.

(ii) To assist departments to specify how far university education in applied science should provide these qualities and qualifications.

(iii) To assist departments to assign priorities to these qualities and qualifications.

(iv) To assist departments to examine on-going teaching programmes in the light of such priorities.

(v) To assist in the examination of assessment techniques in the same light.

(vi) To enable the examination of teaching and assessment to throw further light on the priorities spelled out.

The proposal was accepted by the Leverhulme Trust and in April 1972, Mr. W. T. Koc was appointed to the position of Leverhulme Research Fellow, nearly three years after the original recommendation. A secretary, Mrs. E. Geddes (nee Brown), was appointed shortly thereafter and she was to remain until the end of the project.

The original problem had been seen in terms of the need for the definition of course objectives for assessment purposes. The proposal took this idea further and suggested that objectives be the starting point for the examination of teaching programmes.

Thus, the focus moved : teaching had become the central feature. The approach started with objectives, moved to the teaching programme and then to objectives. The project was an ambitious one since it aimed to work with the undergraduate courses in three distinct disciplines in two universities.

The first phase

Neither Strathclyde nor Heriot-Watt Universities had a department of education or any other department where the project might be naturally based. This was regarded as a positive situation in that the research fellow would not be identified with any pre-existing aspect of the institutions. A management group, consisting of representatives of the two universities who had been actively involved in setting up the project, took the place of a head of department so as to take responsibility for representing the project to the Courts of the two universities and to the Leverhulme Trust. Initially, this group did not consist of representatives of participating departments, although this changed a little in the later life of the project. In addition to the Management Group, a Consultative Group was established which did consist of multiple representatives of the participating departments. The aim of this group was to specifically advise and assist the project in establishing and developing links with the departments.

The first phase of the project began with the computer science departments with the aim of having a 'semi-pilot' stage during the first year. This would provide guidance on the programme to be undertaken with the much larger, mechanical and civil engineering departments, develop appropriate methods, uncover some of the difficulties in the field and establish long-term contacts. Computer science was chosen to start with as they were the smallest departments involved and, moreover, they were the newest discipline; each had been formed during the last ten years. It was originally hoped that this stage would last for two terms and then start to involve mechanical engineering. However, in the event, except for brief encounters with senior staff in all departments and the smallest beginning of work with mechanical engineers at Heriot-Watt, the 'semi-pilot' stage occupied most of the time that Mr. Koc spent with the project.

He described this stage as follows :

> "In the initial stages lengthy tape recorded interviews were conducted with all the members of staff in Computer Science at both universities involved to gain a general view of the nature of the subject, its problems and its priorities as seen by those most clearly concerned with it. These interviews were transcribed and points card indexed to generate a first analysis of the objectives area. This analysis was then cross-checked by interviews with selected members of staff of computer science departments in some universities in Britain and one

abroad (Sweden). Amended groups of possible objectives resulting from this exercise were then discussed at some length with special working parties of more advanced students (from both universities), established for the purpose. Finally, the resulting material has been standardised into groups according to logical and semantic interconnections and presented as a proposed inquiry document to the student working parties, to the computer staff and the consultant, as well as to the managing panel of the project. After discussing the comments received and incorporating the corrections as to the content and format, the document itself has been produced and distributed personally by the project staff to all students of Computer Science in both universities, towards the end of the Easter Term of 1972/73."

Mr. Koc continues in his report of November 1973 :

"The principal use of the student material obtained has been intended to form a base around which the most important contribution to the project, that of the Computer Science staff, could be organised. It was hoped that the ensuing discussion within the departments on the content, appropriateness and validity of the student perception of the departmental aims and performance may lead to formulation of their own structure of priorities and resulting actions. In order to facilitate these, each member of the academic staff in both departments has been furnished with the student results and meetings have been held to discuss them. In consequence of these discussions the project staff have formulated certain specific questions to the academic staff, answers to which were to form the main body of material regarding the subject's current academic objectives."

The response of the staff to this approach was not as wholehearted as had been hoped :

"Although some of the members of academic staff have obviously spent a great deal of time and thought to give the required response to the project staff questions, some of the responses received have been incomplete. This has been a pity since the project's demands on staff time and attention prior to the written questions have been deliberately restrained and, in effect, minimal, to save their goodwill for this main effort."

It should be noted that this approach already represented some deviation from the original aims of the project. The research fellow was taking the key role and taking the initiative in the style and presentation of objectives. An inspection of the documents produced for academic staff at this stage indicates some gap between the mode of expression of the staff in interviews and the form that these expressions have taken in translation by the project. There are signs that the project is one in which the researcher is enlisting the help of academic staff in the exploration of objectives, rather than the staff enlisting the help of the researcher. It was turning into a classical research project in which the aims of the researcher take priority. This is not to impute any special causes for this event, it is the commonest form of educational research and is one in which the researcher believes that he has the best interests of his clients in mind.

As the earlier report mentions, the demands on staff time were very uneven. They were little involved at the start and the major demand on their time came with the receipt of an extensive questionnaire on objectives. The response to this by November 1973 was only six completed questionnaires (60%), which is low when the close relationship between the research fellow and staff is taken into account. One reason that has been given by computer science staff for this was that not only was the questionnaire lengthy, but it used terminology which was unfamiliar to them and was rooted in a conception of their teaching function which was alien to them.

The response from the students was 37% which may stem from similar reasons. Unfortunately, due to the developing illness of Mr. Koc, it was not possible to improve on the response of either group. No active work continued after the late Spring of 1973 and in particular the computer science departments' involvement stopped when the research fellow was not with them.

The project consultant, Professor F.R.Jevons, studied the work of the first phase and recommended that the project be continued with a new research fellow.

The second phase

After a fallow period of about fifteen months, during which time none of the departments appeared to be active in working on educational objectives, the work resumed in September 1974 under the direction of a new research fellow, Dr. D.J.Boud. His brief was to study the work in computer science to see if any of it could be further developed and to establish involvement with the remaining departments.

An initial period was spent examining the impact of the work of the first phase and exploring the kind of work that might be possible with the other departments. The following observations were made at that time :

1. There was a conflict of priorities in the project between the needs of the departments concerned and the demands of a research strategy which aimed to specify detailed educational objectives. It had not proved possible to derive objectives that were meaningful and useful to staff in their appreciation of their undergraduate courses, but a useful function had been achieved in brining staff together within departments and between the two universities to discuss mutual problems. Staff reported that they had found the project worthwhile, but that this had not been related directly to the operational specification of objectives.

2. The strategy that had been adopted depended crucially on the commitments of the staff in departments to the detailed objectives of the research. It is not possible to enable and assist people to do things that they do not think are worthwhile and are not committed to doing anyway. It was found that in the Computer Science departments there was some degree of commitment to the specification of objectives, but that in the departments of Mechanical Engineering there was little or no such commitment. In addition to this the new Working Party on Academic Assessment at Strathclyde was far less endeared to the operational specification of educational objectives than its predecessors in 1969.

3. The research strategy developed by Mr. Koc had been applied to the smallest of the departments involved in the project. Even in that case, and allowing for the health of Mr. Koc, it had not proved possible in a year to do more than to start to approach the problem of specification. It was extremely unlikely that in departments of up to six times the size of Computer Science such an approach could be usefully applied in the time available.

The most important observation was that none of the departments were working on educational objectives before the project staff were appointed, they were only concerned with them when the research fellow was present and all activity on this front ceased when he left. There were no signs that the departments had provided for any particular investment of resources or staff time. The work with computer science had lain for over a year and would have required substantial effort to reactivate it and link it with the future work in mechanical and civil engineering. It was judged that this was not of such high priority as starting anew in engineering and so work with computer science was not taken further. It was clear that the aims and activites of the project would have to be reinterpreted if any worthwhile activity were to result.

From this a new strategy was devised which received the support of the Management Group and which was based on the original aims of the project, but taking into account the then currently expressed views of all staff in the mechanical engineering departments. The various elements of this strategy were described in the Interim Report (June 1975), as follows.

> The first element of the approach is the recognition that the specification of objectives can only be initiated with the agreement that it is a meaningful and relevant exercise. To approach this problem unilaterally would be a difficult and possibly fruitless task. The detailed specification of objectives is not a central element in the revised strategy, although in particular circumstances it can be appropriate.
>
> The second element is the acceptance that it is necessary to start with the issues and problems that exist in the present circumstances and to use these as a starting point for wider exploration of desirable aims for courses. Staff are interested in and concerned about particular issues in the under-

> graduate course. In order to be seen to be useful and to gain acceptance in departments it is important that the project works with staff and accepts, at least initially, their conception of the problems that face the undergraduate course. From that basis it will be possible at a later date to address problems that are recognised by other groups such as students, employers, former students, etc.
>
> The third element is the need to gain the confidence of the staff involved. The project is externally funded and based outwith the departments. There have been anxieties expressed by some staff that they are in some way being assessed. It was necessary from my arrival to reassure staff that this was not the aim, neither overt or covert, of the project. It is essential that staff do not feel they are under threat in the slightest way. For this reason guarantees of confidentiality have been entered into with the departments concerned and with individuals, both staff and students in the departments. It has been agreed that no information about the undergraduate course or anything related to it should be revealed to parties outwith the departments without the full agreement of the staff concerned. This may in some circumstances restrict the amount of information that is publishable, but it is more important to be engaged in worthwhile activity than it is to publish the minute detail of that activity."

These elements were seen as a guide for future activities with the details of what actually was to take place being dependent on the attitudes and outlook of staff in the departments.

The value position of this style of research was made explicit to staff in the participating departments :

> "The research is essentially conjoint research between the project staff and the staff in departments. It is responsive research : it responds to the issues and problems that are present in the situation, not on some pre-established framework or educational theory. It is supportive research : it aims to provide support to staff that are concerned about educational issues in their courses. It is formative : it aims to develop methods of tackling problems rather than assessing problems. It is applied : the chief benefits are for the undergraduate courses concerned."

Since 1969 when the project was formulated, attitudes in the field of research into higher education had changed, the limitations of the objectives based approach had been realised and some of the constraints faced by research projects investigating their own institutions had been explored. It is unlikely that in 1974 the proposal would have been constructed quite in the same manner and the diagnosis of the problem in terms of the need to specify objectives would have been less certain.

Awareness of the sensitivity of this kind of work had increased. For a university or universities to set up a project to examine the workings of its own courses is a radical step, as the objectives and practice of its teaching and examining role is seen to be one of the most personal and central functions. In universities the teaching function of academic staff is one of the most private of any educational institution, for there are very few occasions given for university teachers to be questioned about their objectives and approaches to teaching either by colleagues or students. Syllabuses are normally written in unexceptionable terms that can be subject to extremes of interpretation. The questioning of staff about their aims and objectives by an outsider, albeit a person specially chosen for the task, can be viewed as a gross intrusion into academic freedom. These attitudes had to be considered most carefully when drawing up the programme for the second phase.

The programme

A programme of work was constructed as a result of the initial discussions with the collaborating departments, with the following aims : to increase the awareness of staff of issues and problems in the undergraduate course, to provide a focus for the discussion of these issues, and to assist and enable staff to work towards their solution. There were two parts to this programme. Firstly, for each department a study would be conducted that treated each department in its own right and would aim to construct a protrayal of the undergraduate course in terms of the views of the staff and students who were directly involved with it. It was intended that such a protraval would highlight the problems and issues in the course and would form the foundation for a subsequent phase of work in the following year. It was hoped that extensive discussion in each department would be stimulated by the portrayal and that this would result in specific proposals for future collaborative work to be undertaken with the assistance of the research fellow. In this way the project could fully respond to the departments' needs and not push them into directions that they did not wish to follow.

The second part of the programme would attempt to link the activities of departments in the same discipline so they might share each others' experience and, hopefully, gain insight into some of their problems. Part of this would be achieved by joint activities in a similar vein to those arranged with the computer science departments, but this would be supplemented by a joint survey of the aims of engineering education to be conducted with staff and students in both universities. This aspect of the work would draw on the experience of Mr. Koc in his pioneering work on the aims of the computer science courses.

The Consultative Group to the project had not met often and its membership depended on the availability of staff at the times of its meetings. It had not collectively proved to be an effective body. It was large and its remit was not specific. As the first phase of the project continued with computer science, members of the Consultative Group from other departments had had little to contribute. By the start of the second phase the Group was not familiar with working with each other and members had not been actively pursuing the aims of the project in their own departments. The Group did not meet again after the start of the second phase, but contact with the individual members in the active departments was maintained.

It was intended that in the first year of this second phase work should commence with the mechanical engineering departments and, at the suggestion of Strathclyde civil engineers, that work with civil engineering should be delayed until the final year. This was in keeping with the original time scale but the activities proposed were different.

The production of the portrayal was conducted by the research fellow through extensive field work. One of the subsidiary aims was that through this he could gain knowledge of the field of engineering and gain the confidence of the staff through a non-intrusive presence in the department and at teaching activities. The main methods used were :

(a) Interviews with staff and students. These were open-ended and aimed to allow the interviewees to talk widely and freely about any issues to do with the undergraduate course with which they felt concerned.

(b) Discussions with groups of staff and students. Staff and student groups met separately as the staff had a substantial inhibiting effect on students' expression. These were similarly open-ended, but issues that had been raised in individual interviews were sometimes explored further.

(c) Direct observation of classes and meetings. The aim was to gain first hand experience of the methods and procedures used in the departments and to observe the activities that were reported in discussions and interviews. Field notes were kept of these observations.

(d) Inspection of documents. Materials that were produced for the course or referring to the course were examined. These would include lecture notes, examples sheets, minutes of meetings, examination results, etc.

(e) Small scale investigation. There was a limited amount of investigation of specific problems that were raised in discussions. They would take place using a variety of methods, but would only occur at the specific invitation of the staff who were directly responsible for that area in the department. This would provide an opportunity for joint activities between the project and academic staff which would have a quick and demonstrably useful return.

Internal, confidential reports presenting these portrayals were prepared during the first year and circulated to staff in the departments in the Mechanical Engineering Group at Strathclyde and to those in the Mechanical Engineering Department at Heriot-Watt. The report to this second group was delayed at their suggestion to allow time for the disruption associated with the move of the department from the city to a campus site outside to die down. The reports aimed to capture the variety of view expressed by staff and students and to collate these. No interpretation of the views was made and no recommendations for action were included.

It was anticipated that discussion time in departments would last for no more than a few months and that clear suggestions of future actions could be agreed during that time. This turned out to be grossly over optimistic because of the other commitments of the professorial heads and it was not until nine months later that there was an opportunity for the research fellow to meet the heads of the mechanical engineering departments to discuss the reports. In practice, a programme of work was agreed with individual staff or groups of staff. At Strathclyde this included an evaluation, using mainly a questionnaire approach, of the third and fourth year 'Engineer in Industry and Society' courses, a study of the second year Mechanics of Materials laboratory course which included some innovations, and a longer term investigation of the first year course in engineering which was newly instigated in the 1975/76 academic year. Also, for the second year programme and arising from the contacts established in the laboratory course study, the research fellow took part in a teaching method innovation, skills tutorials, which was to form part of the first year course. Through the encouragement of the project, the member of staff concerned, Mr. T. G. F. Gray, applied for and obtained special funds for this development from the Nuffield Foundation scheme for grants of innovations in teaching in higher education. Further details of the first year engineering course development appear in Part II of this report. At Heriot-Watt the mechanical engineering department did not propose any particular activities after the discussion stage. The common characteristic of all the activities that the research fellow was invited to participate in was that they were all new courses and included innovations in teaching method. No-one who was teaching a well established course requested help with any investigation of it in any form.

The parallel aspect of the second phase programme took as its starting point a survey of the views of final year students in mechanical engineering at Heriot-Watt on the aims of engineering that had been conducted as one of the last acts of the first phase of the project. A list of forty-four aims of a mechanical engineering education had been presented to Heriot-Watt students shortly before graduation. They had been asked to rate these aims with respect to the degree of importance that they felt the aims had been pursued by the course. In addition, they were asked to comment on their ratings and give their general views on the course that they had just completed.

A similar questionnaire was prepared and was distributed to all graduating students at Strathclyde and all staff in the mechanical engineering departments at Strathclyde and Heriot-Watt. An opportunity was taken at this time to ask for the views of staff about the activities of the project. A discussion and analysis of the results of this survey and of other considerations about aims and objectives is included in Part II.

The final component of the programme was one that was to gain increasing importance and, hopefully, will continue well after the end of the project. This involved the sharing of experience between staff in the various participating departments. Within Strathclyde this did occur with respect to the particular new courses that have been mentioned. In the cases of both the Mechanics of Materials laboratory and the 'Engineer in Industry and Society' courses, meetings were held between interested staff in different departments and these focussed on and were stimulated by the contributions made by the project. However, in addition to this it was thought desirable to bring together a variety of mechanical engineering teachers to discuss common problems and to this end a workshop meeting was held on 'Developing Mechanical Engineering Education' in February 1976. Short contributions to stimulate debate on changing aspects of the undergraduate course were given by staff who were involved in innovations in courses at Strathclyde and Heriot-Watt. Furthermore, as a result of particular interest in developing communication skills, Dr. B. Fisher from Loughborough University was invited to describe some aspects of the course that he has been evolving at Loughborough for this purpose. A great deal of enthusiasm was generated from the meeting, but there are no signs, as yet, that there have been any effects on the course, although particular attention was placed on possible future developments at the meeting.

This meeting was followed by another along similar lines in June 1976 which was initiated by the Mechanics of Materials Department at Strathclyde and run in conjunction with the project. Professor Colin Page (University of Bradford) was invited to stimulate discussion concerning his experience of developing an entirely new undergraduate engineering course.

These activities and the wider ones mentioned in the Introduction to the report form part of the expected 'educational fall-out' from the project. That this has been so great is due, we believe, in part to the particular focus of the project, that is, as a problem-centred, responsive approach.

The second phase programme was only fully completed with the mechanical engineering departments. The Strathclyde civil engineers, after some delay, decided finally in December 1975 that they were unable to devote sufficient energy and resources to the project through staffing difficulties and their large involvement in post-graduate work. And because of the successful involvement of the project with the mechanical engineers in the final year, allied with the unavailability of the Strathclyde civil engineers, the involvement at Heriot-Watt in civil engineering was inevitably restricted. The sole activity in this area took the form of a study of a final year undergraduate course in Structural Concrete. This course has many novel features and a brief case study of one aspect was produced in order to share some of the innovative experiences with other engineering teachers involved with the project. The case study, 'Student Appraisal of Research Reports', is included as an appendix to this report.

Issues and problems

The project was ostensibly about educational objectives, but in the event the main effort was not directed to this task. It might, therefore, reasonably be questioned whether the project was successful. This is not a straightforward question to answer. Firstly, the project was based on the assumption that the specification of objectives for courses is a worthwhile process. In fact, only two members of the participating staff shared this assumption strongly enough to want to pursue the original goals when they were interviewed at the start of the second phase and neither of these had made any attempt to specify objectives for their own courses in the way envisaged. Secondly, the project envisaged that the research fellow would "assist and enable" staff in the process of the specification of objectives. Although some staff thought specifying objectives was "a good thing to do", they were not overtly engaged in this process themselves.

The project could not therefore start to pursue its original goals until they were ones to which academic staff were committed. The most worthwhile goal to pursue was thought to be that of increasing awareness about educational issues in the course : to start from where staff were rather than from where they were not. It is hardly realistic to make the arrogant statement that staff should be concerned with the detailed specification of educational objectives. To do that would be to make a premature diagnosis of the needs of the participating departments and channel effort into an area that might be useless in developing the undergraduate courses as they exist.

If we return to the question posed at the beginning of this section : who was the project for ?, we can see that throughout the phases of the project the clients have been the staff in the participating departments, although the two phases have treated this relationship in different ways. The first phase took the task of the project at its face value and through pursuing its course demonstrated some of the constraints that the kind of approach of tackling the specification of objectives directly would face. This learning was incorporated into the design of the second phase which took the existing situation in the departments as its starting point and moved in the direction of the original proposal.

There remains one outstanding problem. In both cases the project staff found themselves in a situation where they had the remit to help staff with a task that they were already doing, or prepared to do. In practice, it was found that this activity was virtually absent. This points to one important feature of work of this kind that must be present if worthwhile work is to be completed and used. That is, that the specification of the problem must be made by the people who are directly concerned. In the present case a research proposal was initiated by a group of staff outside the applied science departments and, at the suggestion of a body that was unfamiliar with the situation on the ground, a group of applied science departments was enrolled. They agreed in perfectly good faith and supported the concept of the project, but were not aware of the implications for themselves, especially the investment that they would have to make.

Another important factor was the extremely long time scale of the project, punctuated by long spells of inactivity. It was nearly three years from the recommendation of the Working Party to the arrival of Mr. Koc and over a year passed between the active involvement of Mr. Koc and the writer. During these fallow periods, although little advance was achieved, the climate in universities towards teaching and learning was changing. Many inter-university projects were funded, innovations were examined, and activity in the training of university teachers developed at Strathclyde and elsewhere. Course evaluation became a legitimate activity, although on a small scale in British universities, and educational ideas evolved. The models of educational research and evaluation current in 1969 drew their strength from the tradition of psychometrics and what is called the 'agricultural-botany paradigm'; by 1975 these models had been severely questioned and found wanting in many respects, not least that of applicability to pressing day to day educational problems. A new paradigm of educational research was becoming established drawing more on the traditions of the social anthropologist than the psychologist. Illuminative evaluation in Britain and responsive evaluation in the United States were seen to be important moves in the direction of addressing questions that practitioners rather than academic researchers thought important.

Against this background the project moved cautiously along. Two research fellows were employed with vastly different experiences and training in different schools of educational research. The question remains : what did the project achieve ? Although this will be considered at greater length in the following sections it is important to note that despite the constraints and the background that has been described, almost, indeed, as direct response to it, a great deal has been learned about the process of educational development in university departments. Of especial significance is that these departments are not the ones that are usually studied : they are in Scottish universities and they are not ones that usually seek the attention of those interested in the world of higher education. Although it would not be true to say that they are typical, it can be said that their problems more closely represent those that are experienced by departments that do not invest an untypically large amount of resources to educational development.

The participating departments

Those departments that had agreed to participate in the original project are as follows. The number of staff, and the number of undergraduate students in each for the session 1975/76 is given.

	Staff	Undergraduates+
Heriot-Watt University		
Department of Computer Science	10	90
Department of Mechanical Engineering	18	149
Department of Civil Engineering	21	265
University of Strathclyde		
Department of Computer Science	9	107
Mechanical Engineering Group*		
Department of Engineering Design and Drawing	11	409
Department of Dynamics and Control	11	
Department of Mechanics of Materials	14	
Department of Thermodynamics and Mechanics of Fluids	25	
Department of Production Management and Manufacturing Technology	13	
[Bio-engineering Unit (postgraduate only - not included)	16]	
Department of Civil Engineering	29	309

Chronology of events

June 1968	University of Strathclyde Senate sets up Working Party on Methods of Academic Assessment under the aegis of the Academic Practice Committee.
June 1969	Working Party reports with a recommendation to set up a study on course objectives.

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* all are autonomous departments, each contributing to the undergraduate BSc in Mechanical Engineering. Includes 65 undergraduates doing a BSc in Production Engineering

+ only includes main subject students

August 1970	First draft submission of a research proposal.
March 1971	Proposal accepted by Leverhulme Trust : grant awarded jointly to University of Strathclyde and Heriot-Watt University for a project on 'Academic Objectives in Applied Science'.
April 1972	Mr. W. T. Koc starts as Leverhulme Research Fellow. Work with Computer Science departments.
Summer 1973	Mr. Koc falls ill.
November 1973	Summary report by Mr. Koc on his work with Computer Science. Professor F. R. Jevons, the project consultant recommends that the project should continue.
	Fallow Period
September 1974	Dr. D. J. Boud starts as Leverhulme Research Fellow, appointed for two years.
October 1974	Dr. Boud recommends a more responsive style of research and begins work with Mechanical Engineering departments.
November 1974	Meeting with Heriot-Watt Mechanical Engineering staff to explain the purpose of the project. They did not seem clear on this.
January 1975	Portrayal of undergraduate course in Mechanical Engineering submitted to staff in the Strathclyde Mechanical Engineering Group of departments.
January 1975	Presentation of an evaluation of the second year Mechanics of Materials laboratory as a departmental seminar at Strathclyde.
April 1975	Evaluation report submitted on the Engineer in Industry and Society course at Strathclyde.
May 1975	Portrayal of undergraduate course in Mechanical Engineering completed for staff in the Heriot-Watt Mechanical Engineering Department. Submitted September 1975 after the department had completed its move to the Riccarton site.
	Nuffield Foundation accept a proposal by Mr. T. G. F. Gray for the development of skills tutorials in the new first year course at Strathclyde.
June 1975	Interim Report to the Leverhulme Trust.
September 1975	Training seminar on small group teaching for tutors on Engineer in Industry and Society course at Strathclyde.
September 1975	Start of involvement with Heriot-Watt Civil Engineering.
November 1975	Heads of Departments in Mechanical Engineering Group at Strathclyde discuss portrayal with Dr. Boud.
December 1975	Second Interim Report to the Leverhulme Trust. Mrs. M.L.J. Abercrombie appointed as new project consultant.
December 1975	Strathclyde Civil Engineers decide that they cannot be involved in the project.
February 1976	Meeting on Developing Mechanical Engineering Education.

May 1976	Report on Student Appraisals of Research Reports - Heriot-Watt Civil Engineering.
June 1976	Meeting on Developing Engineering Education with Professor C. W. Page at Strathclyde.
June 1976	Report to Strathclyde Mechanical Engineering staff on the first year engineering course and skills tutorials.

PART TWO

AIMS IN ENGINEERING EDUCATION

THE FIRST YEAR ENGINEERING COURSE AT STRATHCLYDE : AN EVALUATION

SKILLS TUTORIALS : A CASE STUDY

AIMS IN ENGINEERING EDUCATION

The original formulation of the project addressed itself to the problem of specifying aims for engineering education. This section will examine some of the problems of producing aims and objectives and focus particularly on the aims of mechanical engineering courses at Strathclyde and Heriot-Watt. This section has two purposes. The first is to provide some guidance for university teachers who wish to specify aims and objectives for their courses. Some information will be given, but the main emphasis will be placed on providing a key to some of the literature which may be of practical help. The second is to look more closely at the mechanical engineering courses in the two universities and to compare and contrast some of their global aims using information drawn from a survey of aims conducted with staff and graduating students. In pursuit of these purposes some of the problems and limitations to the specification of aims and objectives will be discussed and some of the work of others who have been concerned with the aims of engineering education will be mentioned.

One of the earliest expectations of the project was that not only would it help in developing objectives for courses but that skill in this activity might be acquired by teaching staff and remain as one of the products of the project. This has been expressed by McDonald[1] in the field of educational evaluation as "the evaluator must leave his tools behind him". Although the specification of objectives has not turned out to be one of the major activities of the project, nevertheless the skill of producing objectives is an important one for university teachers to possess. It is intended that this section will provide some guidance for them in this task.

When the project was proposed in 1969 most current thinking about objectives was rooted in the highly reductionist model of behavioural objectives associated with the work of Robert Mager(2) in the United States. Although the relevance of this kind of approach to the complex world of university teaching was seen in limited areas, there was much opposition to what was seen as a trivialising and endless process focussing on the minutiae of courses. Since that time a great deal of work has been undertaken at both the school and university level in the United Kingdom and the various approaches to the specification of objectives are well documented. Indeed, some of the clearest accounts in this country have been published within the last year. The following discussion will draw on very recent sources - Beard, Healey and Holloway,(3) Bligh, Ebrahim, Jacques and Warren Piper(4) Davies(5) and Stenhouse(6) - to present their advice and views on the subject and to provide an introduction to books that are readily available for further consultation. It is curious to note that none of these sources refers to the others.

Aims and objectives

What is meant by the term 'educational aims and objectives'? Our own aims and objectives can act as guides to what we do and give us some reference point against which we can judge whether we have achieved what we set out to do. In education these words have taken on slightly more precise definitions but are in essence concerned with the same activities. Tyler, in his seminal work on curriculum development, described an objective in the following terms :(7)

> "One can define an objective with sufficient clarity if he can describe or illustrate the kind of behaviour the student is expected to acquire so that one could recognise such behaviour if he saw it."

Here, the objective is defined in terms of what can be expected of students and does not describe the activity or intentions of teachers.

> "Mager (1962; 1975) argues that an 'objective describes a desired outcome of the course'. It will tell what a learner will be able to do after a learning experience. He feels that, 'When clearly defined goals are lacking, it is impossible to evaluate a course or program efficiently, and there is no sound basis for selecting appropriate materials, content, or instructional methods.' A further advantage is that clearly defined objectives permit a learner to evaluate progress, and organize efforts in such a way as to increase the probability of success.
>
> In discussing the characteristics of a good objective, Mager (1962) identifies three components :
>
> 1. Behaviour 'First identify the terminal behaviour by name; you can specify the kind of behaviour that will be accepted as evidence that the learner has achieved the objective.'
> 2. Conditions 'Second, try to define the desired behaviour by describing the important conditions under which the behaviour will be expected to occur.'
> 3. Standards 'Third, specify the criteria of acceptable performance by describing how well the learner must perform to be considered acceptable.'"
>
> Davies (1976)

Objectives constructed in Mager's style are usually called 'behavioural' or 'operational' objectives.

Taba(8) draws a widely accepted distinction between aims and objectives. Aims are broad statements of purpose and intention,

> "The chief function of stating aims on such general levels is to provide an orientation to the main emphasis in educational programmes."

> "The chief function of the more specific platform of objectives is to guide the making of curriculum decisions on what to cover, what to emphasize, what content to select, and which learning experiences to stress."

The use of objectives in course development is but one model of the process and has been criticised on many fronts. MacDonald-Ross(9) has summarised some of the advantages claimed for behavioural objectives and the objections that have been made by opponents of this approach.

"The advantages claimed for behavioural objectives

They form the basis of the only well-worked out method of rational planning in education.

They encourage educators to think and plan in detailed, specific terms.

They encourage educators to make explicit previously concealed values.

They provide a rational basis for evaluation.

They prescribe the choice of instructional means.

They form the basis of a self-improving system.

The system eventually achieves internal consistency.

And the system eventually realizes in practice the aims set in theory.

Objectives serve as a medium of communication.

Objectives can be made the basis for individualized instruction.

The objections to behavioural objectives

No consistent view exists as to the origin of objectives.

In the educational domain no well-defined prescriptions are available for deriving objectives.

Defining objectives before the event conflicts with voyages of exploration.

Advocates do not show how teachers can use objectives to guide unpredicted classroom events.

There are an extremely large number of paths through any body of knowledge, thus reducing the effectiveness of objectives in design.

In some disciplines criteria can only be applied after the event.

Objectives do not prescribe the validity of test items.

Objectives are inherently ambiguous.

The level of specificity problem has never been solved.

Objectives do not communicate intent unambiguously, especially to students.

Trivial objectives are the easiest to operationalize, and this is a problem.

The relevance of goal-referenced models of education can be questioned.

Weak prescriptions lead to cycling. This can be costly.

Lists of behaviours do not adequately reflect the structure of knowledge."

MacDonald-Ross (1973)

Stenhouse proposes yet another objection, based on his knowledge of how educational institutions work in practice :

> "The objectives model of curriculum development is an ambitious and comprehensive theory in the sense that it provides a means of organizing and relating a large range of variables, problems and activities. Such ambitious attempts at theoretical synthesis are necessary and important for the advancement of understanding. But .... such is our lack of firm knowledge of the workings of the institutions with which we are concerned that ambitious theories and models are inherently precarious. They go far beyond the established data. They reach eagerly for coherence and sacrifice firm grounding. In short, they are highly speculative.
>
> And we must be especially cautious with them because they have implications for action."
>
> Stenhouse (1975)

Specifying aims and objectives

If we set aside some of the objections to the objectives approach for the time being we can continue on the assumption that we wish to specify aims and objectives for our own courses.

There are two broad approaches. One is to start with general aims, and gradually make them more precise. The other, which is particularly appropriate when training students for a specific vocation, is to carry out a skills analysis of the job, then classify them into groups of skills so that the syllabus can easily be constructed from them.

General aims to specific objectives

"Baume and Jones (1974) recommend four broad stages :

(a) A brief statement of the overall course aim or objective in about 100 words. This will be rather a general statement but it should say what the students should be able to do at the end of the course.

For example, it could include a phrase such as, 'The student will be able to use given principles to solve a given problem'.

But this is too vague as it stands.

Obviously the principles and problems should be specified.

(b) Therefore, the second stage consists of listing a large number of skills which, taken together, will be recognised as involving attainment of the course aim and overall objectives.

The list should be long and the examples specific.

But as it is obviously impossible to specify all the conditions in which this achievement could be observable, representative examples can be listed. For example, if it is one of the aims of the course that 'students should be able to think critically', this could include writing three specific criticisms of a theory.

If in doubt, a teacher should add to the list because it can always be pruned later.

The difficulty is that it can become too long and unwieldy.

(c) Therefore, the third stage involves classifying the examples to produce a slightly more general sample of what students should be able to do. For example, general descriptions of how critical thought is displayed include :
"Distinguishes facts and opinions",
"Draws valid conclusions from given information or facts",
"States assumptions underlying influences and conclusions",
"Recognises the limitations of given data".

(d) Baume and Jones say that component objectives not previously listed can be derived from these major ones. For example, there may be conclusions the student should be able to draw apart from those listed at the second stage.

If the objectives are well specified the later task of preparing a syllabus diminishes dramatically, not only because the content of the course is determined, but because there is sometimes an evident structure (such as hierarchy or sequence) which will need to be reflected in the organisation."

Bligh (1975)

Analysing skills

"Mace defined a skill as "an ability to produce an intended effect with accuracy, speed and economy of action". With reference to these characteristics of a skilled worker, it is a good idea to analyse his technique chronologically asking certain questions.

(a) What does he do ? (i.e. analyse his actions as far as possible)
(b) What information does he need to know already ?
(c) What information does he acquire at each stage ?
(d) How does this information influence what he does ?

Using this approach, we may go through the four stages similar to those already described.

(a) Writing a general chronological statement of what the student should be able to do (e.g. examine a patient).
(b) List examples of the skills.
(c) Then classify them. (e.g. taking the patient's history, etc.)
(d) Lastly, we may see how other skills fit into this classification.

Bligh (1975)

Some problems

The specification of aims and objectives when undertaken by the individual teacher for his own courses seems a relatively straightforward, though demanding, act. More acute problems arise when the focus is not on a single lecture course, but a collection of courses and activities which form the entire curriculum. The first issue to be met is that of deciding whose aims should be taken into account. Is the curriculum merely the collection of the aims of the individual teachers ? What part do students' aims play in it, or the aims of prospective employers of students, or those of wider society ? And whose responsibility is it to see that the aims of these other groups are considered and most importantly of all : who decides ?

The short answer to this question is that, in practice, the individual departments decide with some moderation from the university as a whole, and from external moderators who are normally academics in other institutions. But, for the purposes of receiving support from validating bodies, it is desirable, from the point of view of the person or persons who initiate the curriculum, that the aims be written in as unexceptionable terms as possible. Indeed it seems, within limits, the vaguer the better. The average syllabus is a very bland and innocuous document with which it is very difficult to disagree. Under these circumstances the control of the curriculum lies very much in the hands of those who initiate the course so that they can be free to pursue matters in the ways that they see fit without outside interference. This is in no way a sinister activity, but it does rest on the assumption that those who teach know best and should, in general, be allowed to teach as they see fit. It is clear that to specify objectives in detailed terms and make explicit all the aims and intentions of the courses is not appropriate under all circumstances and, indeed, is counter-productive in some.

The same arguments apply on the smaller scale within departments. As Medway(11) expresses the problem,

> "Documents setting out the aims of schools or departments tend to sound platitudinous and to remain unread. They're too easy to agree with : the student characteristics stated as desirable outcomes are so unarguably desirable that everyone feels their own practice couldn't possibly *not* be geared towards them : who's going to say they're not trying to make students mature, discriminating, skilful and knowledgeable ? Stated aims never seem to articulate those implicit aims which actually inform a teacher's practice and which result in outcomes visibly different from those produced by the teacher next door."

There are very good reasons for this state of affairs, but as many of them are not concerned very directly with educational issues, they tend to be ignored in the literature.

Statements of aims are a way of making explicit shared assumptions. If there is complete agreement on the underlying values of a particular course or courses then the difficulties that have been mentioned do not occur. Indeed, it is as if one person is designing the course. But if one person is doing it for only his own purposes, the demand to specify aims is not so great. If everyone agrees on what should be aimed for then writing objectives may be seen by some as redundant as "we all know what we want to teach". If there is not a value concensus then it becomes increasingly necessary but increasingly difficult to specify aims. Medway thinks it particularly important to produce aims in this situation :

> "Aims are not any use where there's the possibility of doubt or uncertainty. Then they should help you make decisions because they clearly indicate one line rather than the other. Aims should

> take sides. They should be able to be applied to a particular practice and provide criteria for accepting or rejecting it : 'this works against the aim X we've agreed', or, 'this seems to be achieving something that isn't in our aims - should we have made it an aim ?'
>
> The sort of aims I'd like to see worked out would have some bite. The document containing them would be a working document, constantly referred to. Unavoidable, because they represent real choices of direction, the aims would be contraversial and would be argued over. Also, they would not be produced from armchairs by the exercise of pure reason but would be discovered in the course of working : something you notice about the (students), suddenly alerts you to a whole area of inadequacy you hadn't consciously been seeking to remedy, or you realise one day that what has been tacitly directing your teaching has been some idea of progress that you've never articulated - so you articulate it and start going for it more deliberately."

Unfortunately, he does not recognise the factors that inhibit this process at present. Apart from the problem that university teachers frequently do not invest the same systematic effort into the improvement of their teaching that they do in their research,(12) the situation does obtain whereby university teachers who make their teaching goals explicit to others find themselves in a position where they can be questioned about what they are teaching. It may arise that others might object to what they are doing and seek to modify it. This would produce difficulties and inhibit teachers in the activity of specifying their goals to others but, more importantly, this whole act of making explicit the exact nature and purpose of courses would be at odds with the established university norms of behaviour for academic staff. Too often, ill-thought-out teaching can be hidden by the cloak of academic freedom.

Hamilton(13) takes a characteristically realistic view of the present pluralistic situation with regard to the specification of aims and objectives.

> "It has often been found impossible to generate a set of universally agreed objectives .... When this kind of deadlock is reached one of the following situations is usually employed. (1) a set of behavioural objectives is formulated but never adhered to; (2) a shadow set of aims is developed but only in quasi or non-behavioural terms; or (3) the task is abandoned altogether."

The problems with regard to the effective specification of objectives have not been solved by the project, but they have been exposed. As was described in Part I, it was thought expedient to take Hamilton's third course of action and circumvent the task of producing agreed objectives altogether. A start was made to explore some of the differences and the results of this are described later in this section. Unless a realistic assessment of the situation is made by all those participating in such activities and it is recognised that a situation of likely non-agreement will be met then it is premature for any one person or sub-group to attempt the task unilaterally.

Before proceeding to examine the results of this survey we will look briefly at the work of others in the field of the aims of engineering education.

Work on the aims of engineering education

The work that has been conducted on the aims of engineering is not extensive, especially in Great Britain. It can be divided into two kinds. The first is concerned with the setting of goals and standards for engineering education and is normally conducted by bodies such as special committees of the Engineering Institutions. This is the most common kind of activity and it often produces the impetus for change in the structure of the profession. The other kind sets out to investigate actual aims and objectives as they are manifest in engineering education and engineering practice. It is an empirical, research-based activity and in this country it has mostly been associated with the name of John Heywood and his colleagues at the University of Lancaster and in the United States with the American Society for Engineering Education which has no British counterpart.

In mechanical engineering there has been little said in government reports or reports from the Institution in the last ten years since the report of the Bosworth Committee on Education and Training Requirements for the Electrical and Mechanical Manufacturing Industries in 1966.(14) The Engineering Industry Training Board has been active across the whole front of engineering education and has produced recommendations about 'The Training of Professional Engineers', for example, in 1968.(15) However, the education of civil engineers has been the subject of a major review by the Institution of Civil Engineers by the Chilver Committee, 1975,(16) which, amongst making many recommendations about the complete restructuring of the training for both professional and technical engineers, directs itself to the qualities that it believes are required of the chartered engineer,

> "He combines intellectual and analytical ability with a sound knowledge of civil engineering practice.
>
> He is capable of original and creative thought and, most importantly, can translate this effectively into useful practical achievement.
>
> He will be responsible for the organisation and management of his work and must have the breadth of outlook which will enable him to be mindful of, and guided by, its social consequences, for which he will also accept responsibility.

> He will be able to understand that the contribution of his personal judgement and common sense to decision making may often be as important as the contribution made by scientific analysis and deduction. A sense of judgement may be an inborn characteristic, but can only be developed through a continuing combination of education, training and experience.
>
> To be effective in high office he must be able to communicate well, both with members of the profession and the public.
>
> Some of these qualities will develop during an engineer's career, but only if he continues to keep up-to-date with the advance of knowledge and can profit by experience."

It is interesting to note that this definition reflects the wider responsibilities of engineers which are being recognised as being of increasing importance. However, it does not give any indication about how these desirable characteristics might be developed.

There is a certain amount of evidence that some of these qualities are not being developed as much as would be desired. The Engineering Industry Training Board recently conducted a survey amongst professional engineers, scientists and technologists working in the engineering industry. Part of this attempted to investigate what work they engaged in. A sample of 904 individuals completed log books and a larger sample, 1295 completed a questionnaire on the nature of their work and the skills and knowledge they felt they required to carry it out. They summarise some of their conclusions as follows,(17)

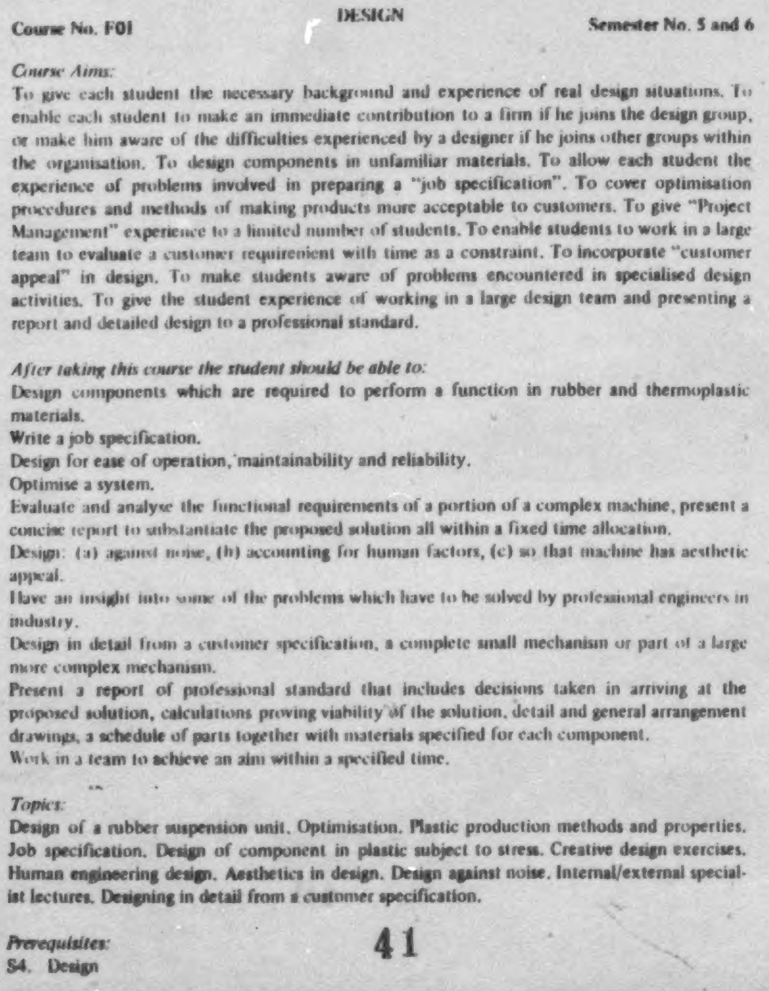
> "The most striking feature, however, overlying all the technical and related aspects of the job of the technologist, was the importance of communication of various kinds. The relative importance of written and face-to-face communication varied between jobs in different functions, but in some form or other communication emerged as the dominant need in the job of all technologists. This is bound to raise the question of how adequately potential technologists are now being prepared for this aspect of their job, and the question relates not only to their training but also to the education they receive before entering industry. Perhaps this is the most important problem area identified by the survey."

This is not just a British problem as is evidenced by the Goals Study of the American Society for Engineering Education.(18) As part of a major six year study of the Goals of Engineering Education from 1961 to 1967, the ASEE conducted a large survey amongst a representative sample of 4,000 practising engineers. 85% completed a 28 page questionnaire, one question of which asked them to look at each subject they studied or might have studied at college and rate the amount they had used it recently and over their whole career and then rate the degree to which they would recommend that each subject should be studied at college. The results show that none of the six most recommended topics were engineering topics -

in order of recommendation they were algebra, general physics, english composition, trigonometry, calculus and verbal communication (speech). They thought that college had been most deficient in preparing them for verbal communication and english composition. This should be compared with similar findings at Strathclyde and Heriot-Watt which will be reported in the next section. The ASEE recommend,

> "only through continuous practice throughout the college program can the needed improvement be realised. All engineering languages should be utilized - verbal (oral and written), pictorial and symbolic. Isolated freshman courses offering little more than minor extensions of high school courses seldom stimulate the student and are ineffective by comparison with the continuous attention recommended here."

Leaving the deficiencies of present educational institutions in pursuing some of these goals we can turn for a moment to the problem of specification and British work that has been undertaken in this area. Two approaches to specification were outlined on Pages 25-28. Firstly, moving from general aims to specific objectives and secondly, that of skills analysis. Aside from the work of Baume and Jones at North East London Polytechnic which has already been quoted, the only example of the first approach in the British context can be found at the University of Bath (applied to a complete undergraduate engineering curricula) in the School of Engineering where all undergraduate courses are described in terms of four headings :



Course No. F01 **DESIGN** **Semester No. 5 and 6**

Course Aims:
To give each student the necessary background and experience of real design situations. To enable each student to make an immediate contribution to a firm if he joins the design group, or make him aware of the difficulties experienced by a designer if he joins other groups within the organisation. To design components in unfamiliar materials. To allow each student the experience of problems involved in preparing a "job specification". To cover optimisation procedures and methods of making products more acceptable to customers. To give "Project Management" experience to a limited number of students. To enable students to work in a large team to evaluate a customer requirement with time as a constraint. To incorporate "customer appeal" in design. To make students aware of problems encountered in specialised design activities. To give the student experience of working in a large design team and presenting a report and detailed design to a professional standard.

After taking this course the student should be able to:
Design components which are required to perform a function in rubber and thermoplastic materials.
Write a job specification.
Design for ease of operation, maintainability and reliability.
Optimise a system.
Evaluate and analyse the functional requirements of a portion of a complex machine, present a concise report to substantiate the proposed solution all within a fixed time allocation.
Design: (a) against noise, (b) accounting for human factors, (c) so that machine has aesthetic appeal.
Have an insight into some of the problems which have to be solved by professional engineers in industry.
Design in detail from a customer specification, a complete small mechanism or part of a large more complex mechanism.
Present a report of professional standard that includes decisions taken in arriving at the proposed solution, calculations proving viability of the solution, detail and general arrangement drawings, a schedule of parts together with materials specified for each component.
Work in a team to achieve an aim within a specified time.

Topics:
Design of a rubber suspension unit. Optimisation. Plastic production methods and properties. Job specification. Design of component in plastic subject to stress. Creative design exercises. Human engineering design. Aesthetics in design. Design against noise. Internal/external specialist lectures. Designing in detail from a customer specification.

Prerequisites:
S4. Design

An example of the other main approach, skills analysis, can be found in the work of Heywood(20) and his colleagues.(21) The standpoint of Heywood's work is that, "education and training objectives should be derived from the work undertaken and to be undertaken by engineers".(20) He criticised much of the previous work work on engineering curricula:

> "It had been conducted at a much too general level so that individuals were free to impose their own interpretations on the statements of discussants .... what was needed was a thorough simultaneous discussion of behavioural objectives, methods of assessment and learning experiences."

Heywood's approach was to study engineers at work and to examine what tasks they actually performed and their attitudes to their work. Using Kelly's personal construct theory, Youngman looked at the ways engineers perceived the abilities they required in their jobs in one particular firm.(22) He derived 14 separate ability clusters, each comprising from 11 to 36 constituent operations. From this a check list of engineering operations which finally included 434 items was prepared and circulated to all the participants who were asked to tick off the operations they thought they did in their jobs. These results were subjected to a hierarchical analysis to classify both engineers and abilities. In his summary of this work Heywood concludes,

> " the analysis of abilities clearly supports the view that .... most engineering functions involve personnel in problem-finding and problem-solving. All personnel are involved in making decisions. All personnel have to make judgements about themselves and others in the way in which they interact with others both in the horizontal and vertical sections of the hierarchy."
>
> "The ability groups highlight the differences between industrial activity and college learning. If there is a gap to be bridged it lies in enhancing those skills of critical thinking which readily facilitate the transfer of learning to now unfamiliar circumstances. This implies that activities,such as brainstorming, value analysis, critical path planning, should be encouraged in the undergraduate practical curriculum as part of broadly based projects or feasability studies which take students outside their experience to date."

Aims of an Undergraduate Mechanical Engineering Education

One of the specific activities of the project was a brief survey of the aims of the undergraduate course, as seen by staff and graduating students of the two universities. It was not part of the principal responsive approach described earlier although staff had expressed interest in the exercise. Neither was it a very substantial part of the project's work. It should be seen as entirely supplementary to the main activities which are described elsewhere. One of the chief reasons for the survey was to have some basis of comparison between the aims of the two courses. Such a contrast and comparison did not emerge from the portrayals as they were each rooted in the problems and issues in each institutions and these did not include comparative concerns. It was thought desirable that a brief profile of aims for each course as seen by the two main parties should be produced.

The formulation of the aims which were included in the survey were taken from those prepared by Mr. Koc in the first phase of the project. He had derived a list of 44 aims of mechanical engineering education from his last interviews with mechanical engineering staff at Heriot-Watt and from the literature and had administered a questionnaire to final year students at Heriot-Watt shortly before they graduated.

These aims were taken, without modification, for the survey of mechanical engineering staff and students at the two universities. This was done to provide continuity and a stable basis for comparison between the four groups. It is important to recognise the rationale for the particular list of aims. Firstly, no attempt was made to prejudge whether the aims could or could not be developed by an undergraduate course. They did include qualities that many people would regard as personal qualities of an individual that could or should be little influenced by the university. This was deliberate. To do otherwise would be to make assumptions about how staff and students would respond. It was expected that some respondents might be a little irritated by this but it was judged to be more important to achieve completeness.

The list of 44 aims was presented to all staff and to all graduating students at Strathclyde and Heriot-Watt. They were asked to rate each aim on two factors :

"to what extent do you think this is important ?" (Scale A)

"to what extent did the university/course help to develop this aim ?" (Scale B)

They were provided with a four point scale from 0 (not at all) to 3 (greatly).

In addition, they were asked to provide additional comments about those aims that they rated particularly highly or lowly on Scale B and to give any other comments that they wished to make about the course, the project or the questionnaire.

The responses for each group were as follows :

Strathclyde students (omitting 15 overseas residents)	n= 57	(55 %)
Strathclyde staff (only mechanical engineers)	n= 47	(76 %)
Heriot-Watt students*	n= 20	(80 %)
Heriot-Watt staff	n= 9	(53 %)

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*The Heriot-Watt students were surveyed by Mr. Koc in Summer 1973. All other groups were surveyed in Summer 1975.

Aims Analysis

A two way analysis of variance F-test with unequal sample sizes was conducted on the results and individually statistical significances were further analysed using t-tests.(23)*

The analysis is presented under the following headings :

(a) The most and least important aims as judged by all groups
(b) The most and least successful aims
(c) Discrepancies between importance and success
    (i) Overall for all groups
    (ii) For staff and for students
    (iii) For each institution

Important Aims

The five *most important* aims across all groups, in order of importance, were :

1. engineering commonsense
2. ability to use/apply knowledge
3. understanding of general principles/theory of mechanical engineering
4. competence in problem analysis and calculation
5. ability to evaluate material (to use evidence)

Of these aims, the courses were rated as most *successful* in helping to achieve "competence in problem analysis and calculation" and "understanding of general principles/theory of mechanical engineering". They were judged to be much less successful in "ability to evaluate material (to use evidence)" and particularly "engineering commonsense".

The five *least important* aims were

40. commitment to personal advancement
41. experience of computer use
42. interest in a specific field in mechanical engineering
43. preference for uncertainty/adventure/chance
44. preference for a regulated lifestyle

Of the least important aims, the courses were very successful in "experience in computer use", espcially at Heriot-Watt, and "interest in a specific field in mechanical engineering".

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* The advice and help from Dr. W. Cheyne, Department of Psychology, University of Strathclyde is gratefully acknowledged.

Successes of the courses

The courses in both institutions were judged on average of both staff and students to have been most successful in :

1. understanding of general principles/theory of mechanical engineering
2. competence in problem analysis and calculation
3. knowledge of particular facts and terminology of mechanical engineering
4. ability to comprehend new material accurately and quickly
5. ability to use/apply knowledge

"Knowledge of particular facts and terminology of mechanical engineering" was rated more highly by staff than students in both institutions for both importance and success (Strathclyde $t = 2.60$, $p < .05$; Heriot-Watt $t = 4.32$, $p < .001$).

The least successful were thought to be :

40. practical experience of engineering procedures
41. ability to be communicative, articulate in speech
42. sensitivity to people, situations
43. preparation for taking managerial decisions
44. ability to organise other people when necessary

Of those thought least successful, one, "ability to be communicative, articulate in speech" was rated as of very high importance, and forty, forty-two and forty-four were of moderate importance. In summary, the technical aims of the course were thought to be well achieved but the human skill aims were thought to be very badly achieved by both staff and students in both institutions.

Differences between importance and success

The aims ratings were further examined to look for the greatest discrepancies between importance to staff and students and their perception of the success of the courses in achieving them. Two types of discrepancy can be distinguished. Those in which importance is rated higher than success : these will be referred to as the 'underdeveloped aims'. And those in which success is rated higher than importance : these will be termed the 'overdeveloped aims.' Perhaps not surprisingly, overall there were more (42) 'underdeveloped' than 'overdeveloped' (2) aims.

These general figures mask some important individual differences between groups and these will be discussed.

The major 'underdeveloped aims' were ($F > 80$, $p < .001$)

1. ability to be communicative, articulate, in speech
2. ability to organise other people when necessary
3. willingness to take responsibility
4. practical experience of engineering procedures
5. sensitivity to people, situations
6. engineering commonsense
7. readiness to question accepted ideas
8. ability to communicate in writing
9. preparation for taking managerial decisions
10. realism
11. awareness of general human problems
12. ability to co-operate with others
13. tolerance of other people
14. ability to use/apply knowledge
15. ability to evaluate material (to use evidence)
16. ability to understand/consider contrary opinions
17. flexibility (ability to try many alternatives)
18. ability to cope with unfamiliar situations
19. interest in industrial scene in general
20. willingness to share concerns of others
21. personal security
22. understanding of industrial relations
23. ability to keep going when things go wrong
24. readiness to learn about something completely different
25. understanding of mechanical engineering in relation to other subjects/areas
26. understanding the relationship between parts (subject areas) of mechanical engineering
27. sense of ambition (personal expectations)
28. knowledge of management techniques
29. ability to think three dimensionally

Almost all of these aims refer to non-technical abilities and characteristics : working with people, seeing the subject in a wider context, personal qualities and managerial skills.

The ninth aim on this list, "preparation for taking managerial decisions", showed a marked discrepancy between staff views and student views of its importance. Students in both institutions rated it much higher in importance (Strathclyde $t = 8.61$, $p < .001$; Heriot-Watt $t = 10.47$, $p < .001$) than did the staff. Both staff and students did agree that the courses did little to develop this aim although Strathclyde staff rated both the importance of the aim ($t = 2.70$, $p < .01$) and the success of their course in developing it ($t = 5.31$, $p < .001$) higher than did Heriot-Watt staff.

The twenty-eighth aim, "knowledge of management techniques", showed a similar profile with the additional features that the two groups of staff saw no significant difference in its importance ($t = 0.48$, N.S) and students at Strathclyde rated it higher in both importance ($t = 4.13$, $p < .001$) and realisation ($t = 2.22$, $p < .05$) than Heriot-Watt students.

For the seventeenth aim on the list, "ability to cope with unfamiliar situations", the students in both institutions rated the courses more highly than the staff in achievement (Strathclyde $t = 7.52$, $p < .001$; Heriot-Watt $t = 2.11$, $p < .05$). A similar pattern exists in the aim "ability to keep going when things go wrong". Students feel that the course is pursuing this aim much more than the staff do (Strathclyde $t = 6.22$, $p < .001$; Heriot-Watt $t = 6.39$, $p < .001$). Heriot-Watt students show no significant difference between the importance and realisation of the aim, ($t = 1.70$, N.S), and they do rate their course higher in realisation of the aim than the Strathclyde students view of their course ($t = 4.67$, $p < .001$). "Understanding of general principles/theory of mechanical engineering" was rated by all groups to be the most successful aim. It shows no overall sign of underdevelopment but staff in both instituions judge it to be so (Strathclyde $t = 5.53$, $p < .001$; Heriot-Watt $t = 6.69$, $p < .001$). The students rate it adequately covered (Strathclyde $t = 1.39$, N.S; Heriot-Watt $t = 1.06$, N.S).

Turning to the 'overdeveloped aims' we find that of the only two represented, "experience of computer use" and "interest in a specific field in mechanical engineering" there is no overall difference between realisation and importance for all groups. However, Strathclyde staff rate their course more highly than Heriot-Watt staff on the achievement of "interest in a specific field of mechanical engineering" ($t = 2.89$, $p < .01$), and there is a major difference between the two universities on "experience of computer use". At Strathclyde students think that this aim is 'underdeveloped' ($t = 2.84$, $p < .01$), but staff feel it is being adequately pursued ($t = 0.82$, p N.S), whereas at Heriot-Watt both groups think that "experience of computer use" is 'overdeveloped' (staff $t = 4.15$, $p < .001$; students $t = 3.89$, $p < .01$). The differences between the two universities being (Students : importance $t = 4.60$, $p < .001$; success $t = 16.84$, $p < .001$; Staff : importance $t = 11.12$, $p < .001$; success $t = 0.78$ N.S).

Other differences between groups and institutions

Of the aims that have not been discussed, only two show any significant differences in the various ratings.

"Interest in engineering design" is rated quite highly (sixth) in terms of success by all groups. Both Heriot-Watt staff ($t = 1.00$ N.S) and students ($t = 0.60$, N.S) think this is adequately realised in their course, but at Strathclyde staff ($t = 5.05$, $p < .001$) and students ($t = 7.54$, $p < .001$) rate it to be 'underdeveloped'.

"Commitment to personal advancement" is not thought to be a very important aim by any group. At Strathclyde students rate it higher than staff in terms of importance ($t = 9.15$, $p < .001$) and realisation ($t = 8.70$, $p < .001$). These differences are much less at Heriot-Watt : importance ($t = 1.35$, N.S), realisation ($t = 2.46$, $p < .05$). There is also a significant difference between staff; Heriot-Watt staff rate this aim higher than Strathclyde staff on both factors : importance ($t = 4.23$, $p < .001$), realisation ($t = 2.46$, $p < .05$).

Opinions of the aims of the course

The analysis of the survey data provides only a limited perspective on the courses and the views of staff and students on the aims of an undergraduate education. This is supplemented with the comments that were written on the questionnaires in response to some open-ended questions.

The first two questions asked students to look at the ratings that they had given on the factor, "to what extent do you think the course/university has helped you to develop this?", to comment on those aims that they had rated particularly highly or lowly and say how they thought that the course had helped or could have helped more in developing them. In the staff questionnaire this section was shortened and they were asked to comment in addition on the questionnaire generally and on the project itself. Students also used a final open section on 'Comments' to make points of a similar nature.

The types of comment can be broadly classified into the four areas : about the aims provided, positive views on the course, negative views on the course, and about the project itself.

In quoting student comments from open-ended questions it is very difficult to judge the number of students that subscribe to any view. When the words, 'many', 'some' or 'few' are mentioned these are my subjective estimates; 'many': 30-60%, 'some': 10-30%, 'few': 5-10%.

The aims

A few students and a larger number of staff were concerned that many of the aims were not those that the course could or should be involved in developing, for example,

> "I think the course should be carried on as a science based course as all the available time is needed to study engineering. The university should not interfere in any way with any of the questions in list B which I circled 0."
>
> Strathclyde student

> "I feel that development of these areas (zero rated aims in list B) is best left to the individual. They are essentially character traits and should not be instilled in the students as a whole."
>
> Strathclyde student

> "Our principle aim at the university should be to produce first and foremost competent engineers and in my opinion anything which distracts or diverts this aim at the university undergraduate level is of no consequence or of little value and is in some cases obstructive. I believe that the questions 21-44 under heading B fell into this category and in no way should form the basis or aim of any engineering course at the undergraduate level. Maybe after having some engineering experience an engineer might want to 'broaden' his experience to such ends."
>
> Strathclyde member of staff

Two staff felt that the list was so entirely inappropriate on which to judge engineering education that they declined to complete the questionnaire. One staff member who did return the questionnaire expressed a similar view,

> "I have tried to fill this in according to the instructions but frankly I think it is worse than useless because it is wide open to misinterpretation of the kind that could do harm to engineering as a profession, industry and the universities. It seems to me to have been made up by a person who knows very little about the manufacturing industry and the gory details of how wealth is produced."

In contrast to this, others point out that they are concerned that the course is too exclusively technically biassed and want to widen the undergraduate course as it exists to include some of the aims which others would reject :

> "To me there is a complete clash of interest between 'university education' and 'mechanical engineering education'. I think that if we concern ourselves with the latter - the training of a 'good' mechanical engineer, then we are in grave danger of losing sight of the former. My view is that we are a university - the fact that we are the mechanical engineering faculty is secondary to that."
>
> Strathclyde member of staff

> "The tendency is to produce a student ingrained in present knowledge, dedicated to his own work, insensitive, almost intolerant of others, not trained nor geared to make optimum use of his own abilities."
>
> Strathclyde member of staff

Student views of the course*

Some of the students took the opportunity of the questionnaire to appreciate the good aspects of the course and present some fulsome praise :

> "The whole process of learning was complete at Strathclyde. The department of Mechanical Engineering taught not only from a sound academic knowledge of their subject but, far more important, from the setting of an example of enthusiasm, dedication and a willingness to impart their knowledge to the student. Despite the fact that one goes to university to study a particular subject, the course content is a small part of a much greater entity. The whole concept of education and learning is understood and used efficiently by the Mechanical Engineering department. The department shows that engineers are not only intelligent academics but have commonsense and, above all, an interest and awareness in people."

> "The course has given an insight into the complexity of engineering problems, shown how some of them are approached and finally developed the ability to communicate the findings. The university has matured me personally, politically and professionally."

> "I believe that any university course is important more for its ability to develop one's ability to think, question, analyse and deliberate than for learning one specific topic. In that respect no other course succeeds better than mechanical engineering (particularly the course at Strathclyde), eg. no course could have provided me with a better grounding and base from which to tackle the accountancy profession."

Others give a more neutral assessment of what they have gained :

> "Generally the course concentrated on problem analysis and calculations and after four years you can become fairly competent."

> "I have learned some of the terminology and basic concepts of mechanical engineering due to the number of hours required in study. Mainly due to the lecturers' influence I also found that obtaining the 'exact' answer to a problem was not necessarily a useful solution if constraints like 'time allowed' were not considered."

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*The views of Heriot-Watt students have been recounted in an earlier report, October 1975.

Specific attributes or deficiencies of the course were mentioned. These include what some students experience as a lack of realism in the course and observed that in some ways it did not take account of students' likely future activities :

> "I think people at university should try and emphasise to students that the things they learn at college need not be applied when they go to get a job. This is probably industry's fault but it is a fact of life. Industry is not really as up to date as it is made out and there are very few outlets for really technical jobs."

> "I feel the course is practically very narrow. As with many courses in fields apart from engineering the importance of engineering when practised in today's environment should be more than just emphasised. Perhaps the study of projects concerning social awareness in engineering or blunders in engineering, eg. Tory Canyon, Flixborough."

> "The course is not geared to provide the graduate engineer that is required for industry due to emphasis on theoretical rather than practical engineering."

> "The university and course was not bad, but there is still great scope for improvement. I suggest a much greater emphasis on everyday engineering problems and on the effects of engineering practice on the lives of people and the environment."

Some specific suggestions about this were made :

> "The course did not cater for anything except mainline engineering. There was very little about side issues (eg. politics, personnel, marketing, etc.) and their direct connection with practical engineering. This should be done via up to date practical situation simulation, if not via real situations. The careers aspect was disastrous, as was individual attention, careers must be stressed in 3rd year."

> "Perhaps the course is too theoretical to the point where general engineering topics are ignored. Exam results and individual class performances are given too much priority."

> "Direct contact with those people in the outside world who have first hand knowledge of the reality of social conditions both in relation to employment in industry, etc., and to life-styles, eg., socially deprived groups, racial minorities, etc. The above should replace condescending talks from chappies who've made it to the top."

This emphasis on the lack of practical involvement in the course is stressed in terms of industrial experience both by those with and without such experience:

> "I feel that the younger graduate is not getting the necessary experience to equip him properly to enter industry with the ability to appreciate that people are important and then that academic work is necessary."
>
> Strathclyde student with
> 14 years industrial experience

> "For students like myself who came to university direct from school, at least two vacations should be spent in industry - this should be compulsory in order to complete the course - the university must help find these jobs."

> I went to university, not because I wished to, but as a natural progression from school. I feel that the engineering BSc course should be only open to those who have spent at least two years in the industry (for their own good), or the university should supervise industrial training from the summer before the student enters first year."

Other students were appreciative of the detailed engineering course that they had taken but were concerned that this was provided at the expense of possibly more important factors :

> "I felt university as a whole gave me a good engineering education but tended to mould people into characterless robots (zombies) without much personal initiative."

> "Having had experience abroad and having met French, German and Italian engineers (all of whom spoke fluent English) I feel that although the standard at Strathclyde is high, the course is very limited in what it can offer."

> "Rather than concentrate on trying to produce a mass of design or production engineers the university should emphasise what a large and expanding career field a mechanical engineering degree can offer. Too much emphasis was put on a person's academic capabilities rather than the person as a whole."

For a small minority the course was too much :

> "The mechanical engineering course I completed was most distressing : enormous classes, impersonal tuition, academic assessment based on yearly 3-hour sweat session against the clock : absence of social scene involving students and academic staff."

> "Spending 40 minutes out of every 50, 3 hours a day, 5 days a week for 4 years copying notes off a board is not my idea of learning to think for yourself !!"

Some specific suggestions were made with regard to particular aspects that students would like included or skills that they would like to see developed further :

> "It would help greatly if we were given information on where to look for information, where it comes from and where to find the usual data given in tutorials and lectures instead of just being given it out of the blue."

> "It is as important to cover the role of engineering management as competence in problem analysis and calculation."

> "I think the most important subject left out of the mechanical engineering course is industrial relations, since this is an ever increasing problem in British industry today."

> "No mention was ever made of new developments and their possible effect on our future work."

> "More lectures from professional engineers outwith the university."

> "The course does not allow people to make any other decisions than to choose the final subjects. The students should be encouraged to make some decisions."

Other frequently mentioned proposals were for more small-group teaching and seminar work to help develop skills in working in groups and teamwork, help in communication skills, eg. by giving short lectures or presentations, and the use of case studies in exploring some of the social dimensions of engineering.

The chief features of the course that emerge from the comments supports that of the aims analysis. The course is seen to be excellent and of a high standard from the theoretical and technical point of view, but narrow in outlook. It was thought that the practical aspects of engineering are under-emphasised as is the relevance to environmental and social problems. The staff assume that the students will enter design offices or undertake research and development work and the courses are seen to be orientated to these ends. Insufficient attention is given to the wider field, even within engineering. Finally, some students were concerned that their analytical abilities were being developed at the expense of their expressive abilities.

None of this should be taken to imply that the course should change. It may be that the course is achieving those things that the students are asking for without their realising it and that all that is required is that this be pointed out to them. On the other hand some or all of the students' views may be valid, and some of these views are supported by members of staff.

Staff views of the course

In many ways, staff views echoed those of students although they expressed themselves rather differently :

> "Above all else, when all the engineering type problems have been solved this is only the beginning. An awareness of general human problems that exist and are likely to arise as a result of Engineering Activity should be outlined. The course 'Engineer in Industry and Society' certainly gives some time to do this but perhaps the Technology subjects should be encouraged to do so."
>
> "We always appear to hide behind the lack of time or large number of student barriers for doing anything to promote better communication, both written and spoken, among our students."
>
> Strathclyde staff

> "Mechanical engineering of the modern world has become an interdisciplinary science/(art). There is not sufficient attention paid to this in the engineering courses."
>
> "The 'ivory tower' mentality is still very strong. Not enough attention is paid to preparing the graduates in these areas which are possibly the corner stones of industrial peace and national prosperity."
>
> Strathclyde staff

> "The course seems to emphasise 'scientific' approach to engineering and gives no practice on commonsense approaches."

> "Subjects are taught in 'compartmented' way and understood by students in that way."

> "Course emphasises 'tidy' closed solutions to problems and leaves students with the feeling that there is a problem and the answer."

Very many staff were worried about the written and verbal skills of the students and suggested a variety of ways in which these can be developed. However, some of these thought that responsibility for this could be placed on the Engineer in Industry and Society course and did not see it as something they should be developing in their own courses.

The staff made little mention of the relevance of the course either to a student's future career or to general social and environmental problems.

Comments on the aim of "engineering commonsense" suggested that this was not something the university could do much about, one person mentions pointedly, "This is best 'taught' in industry. Some of our best honours students have possessed little of this !"

And the emphasis on the theoretical content of the course is defended by a number of staff who felt all the aims to be important :

> "Different universities concentrate on different aspects - so they must since no-one in a 4 year course can cover all aspects. The newer universities such as Strathclyde and Heriot-Watt tend to concentrate on the practical aspects and act as a training ground for industry. The older universities pitch their courses at a higher theorist level and graduates usually require some 'industrial orientation'. Each type tends to sneer at the other but both are essential. Industry needs engineers with practical ability : what is often forgotten is that it also needs engineers, well versed in theory who can keep abreast of developments in that area and, in the long term, apply new ideas to practical situations. Otherwise the gulf which exists at present between engineers and mathematicians doing research in engineering subjects will widen even further. The esoteric mathematical studies of today are the codes of practice of tomorrow. But somebody has to know both sides of the business in order to compile the tables."
>
> Heriot-Watt staff

Many of the staff appreciated the importance of the aims but pointed out that they and their courses have only a part to play in the much wider educational environment:

> "To develop these faculties is a long process starting long before reaching university. They can be improved by the course but cannot be established if not already possessed."
>
> Strathclyde staff

> "Many of the aims refer to, in my opinion, an almost perfect graduate ready to meet the big bad world at large ..... a degree course cannot produce the complete man - not by a long way."
>
> Strathclyde staff

> "Many of the important abilities that an engineer should acquire from his education can only be acquired by much practice, time for which is not available in the present course."
>
> Strathclyde staff

> "It must be remembered that engineering education does not end with graduation. These aims are examples of areas where suitable education can only be gained in an industrial environment. Attempts by purely educational establishments to satisfy these requirements can only be artificial."
>
> Strathclyde staff

One person classified the aims under three categories :

(i) those relating to academic training

(ii) those relating to the general education of a professional engineer obtained before and after academic training

(iii) those relating to the general education and personality of anybody.

This was a classification that seemed implicit in many of the responses. Everyone agreed that the undergraduate course should be primarily concerned with the first category and to a lesser extent wi[illegible] others. Different people drew the boundaries at different aims and this has many implications for what should be included in the course. Priority would always be given to the academic training but there was not agreement on how far this should go ; some see the academic disciplines as very circumscribed and narrow whilst others think it essential that these have aims other than the strictly academic ones.

> "Remember that the aims of a first degree are limited to achieving a faculty for certain academic disciplines and habits of thought and remember also that learning does not finish with graduation. Undergraduate and postgraduate training schemes are run by industry and MSc and other courses exist. We are not trying to produce 'engineers', we are trying to produce people who are capable of becoming engineers within another 2-4 years (the poorer ones will take longer)."
>
> Strathclyde staff

Some staff were reticent about making judgements of the course as it presently existed as they did not think that their perspective from within one department amongst many contributing to the course was a complete one :

> "It must be said that this exercise is rather artificial when applied to mechanical engineering education at Strathclyde University. Because of the structure of the mechanical engineering group, assessment of educational standards in departments other than one's own is difficult to achieve. The only feedback one gets about the overall course standard is in discussion with students. This is not the best way to form an opinion on another department's work."
>
> "The undergraduate course in this University is excellent, students graduate with a basic engineering knowledge that is second to none. One does get the impression though, that the students still think in terms of separate units, Thermodynamics, Materials, Dynamics, etc. They should be able to inter-relate parts of the courses, but they cannot. This is most evident in their Mathematics and its application to engineering problems."
>
> Strathclyde staff

And others pointed to the structure of the Mechanical Engineering Group as not being helpful for dealing with problems in the course :

> "Too much emphasis in the present course is on the rapid gathering of facts to be regurgitated at a later date. This appears to be the result of almost total non-co-operation between departments, each anxious to do the maximum amount of teaching, if necessary, at the expense of other departments (eg. the new first year course). The student's interests come a very poor second - at present he has such a bulk of information to deal with that he has no time to put it in perspective."
>
> Strathclyde staff

In commenting specifically on the questionnaire a wide range of opinion was expressed; from those who thought it too vague and non-specific to those that thought it too demanding of time and effort; and from those that welcomed the opportunity to express their views to those who thought that any such activity would be an unfortunate intrusion into matters that might not sensibly be discussed.

Reflections

Some of the issues raised will be discussed at greater length in the next section. However, a few immediate reflections may be made. Firstly, the questionnaire made no attempt to imply that anything should be part of the course : it was intended to be entirely descriptive, not prescriptive. Some of the staff seemed to make the assumption that the questionnaire was suggesting that certain aims ought to be featured in the course and as a result completed the form begrudgingly or not at all. This observation is important in terms of questionnaire design.

No matter what the apparent design of a questionnaire some recipients will impute other motives and will respond in terms of their assumptions of what the questionnaire designer is aiming to do. This will occur in all questionnaires and it is encouraging that the relationship between the project and the staff members was sufficiently close for such doubts and fears to be openly expressed.

Secondly, it is interesting to note the extraordinary consistency of response between both groups of staff and both groups of students. The courses appear to be pursuing very similar global aims, to have similar strengths and similar deficiencies. This supports the subjective impression that is experienced in interviewing staff and students that there is a very high degree of concensus about the values of the course and of engineering as a discipline. A body of shared assumptions exist and are not obviously being questioned by anyone in the samples although in the wider sphere proponents of alternative technology would strongly question this concensus view.

Finally, it is important to realise that although this survey and expression of opinions have referred to courses at Strathclyde and Heriot-Watt in mechanical engineering subjects, the problems raised are certainly not exclusive to those institutions but reflect some of the problems of engineering education which are international. One of the fluent critics of engineering education in the United States, Samuel Florman,(24) himself an active engineer, has written :

> "Part of the problem is surely the stultifying influence of engineering schools. In too many of these institutions, the least bit of imagination, social concern or cultural interest is snuffed out under a crushing load of purely technical subjects. The situation appears to be improving, although a whole generation of engineers has been disfigured."

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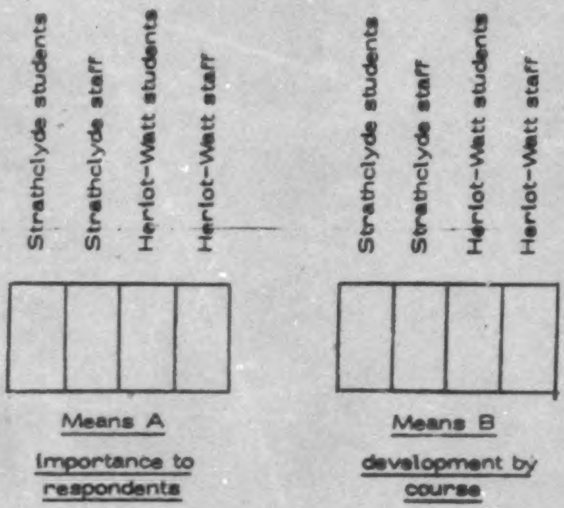
AIMS QUESTIONNAIRE : SUMMARY OF RESULTS

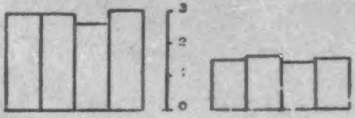
Table ranking aims in order of means of importance (A) and development by course (B)


Strathclyde students
Strathclyde staff
Heriot-Watt students
Heriot-Watt staff
Strathclyde students
Strathclyde staff
Heriot-Watt students
Heriot-Watt staff
Means A
importance to respondents
Means B
development by course

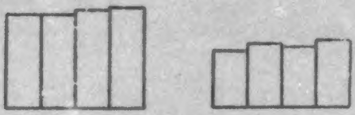
KEY

Aims are ranked in order of Means A

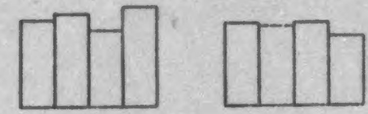
1. engineering commonsense



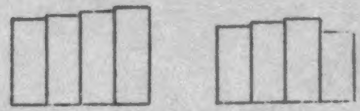
2. ability to use/apply knowledge



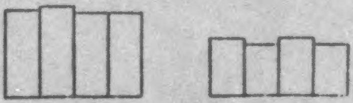
3. understanding of general principles/theory of ME



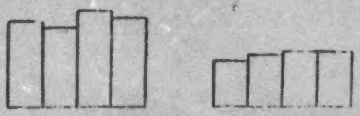
4. competence in problem analysis and calculation



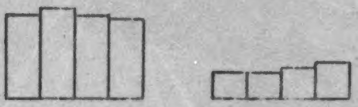
5. ability to evaluate material (to use evidence)



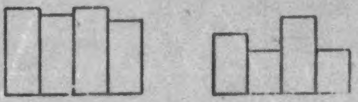
6. ability to co-operate with others



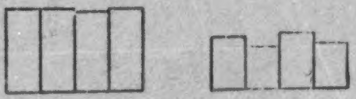
7. ability to be communicative, articulate in speech



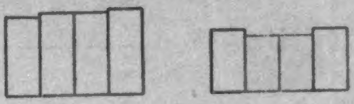
8. ability to keep going when things go wrong



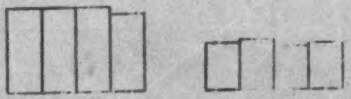
9. flexibility (ability to try many alternatives)



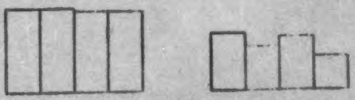
10. ability to comprehend new material accurately and quickly



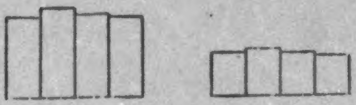
11. realism



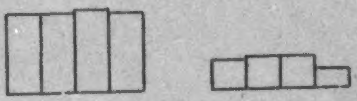
12. ability to understand/ consider contrary opinions



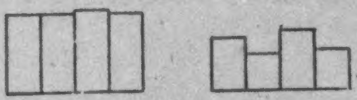
13. ability to communicate in writing



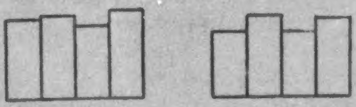
14. willingness to take responsibility



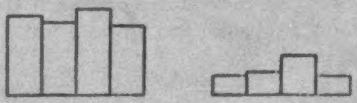
15. ability to cope with unfamiliar situations



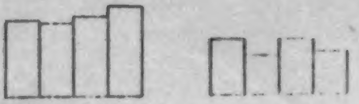
16. knowledge of particular facts and terminology of ME



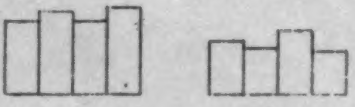
17. ability to organise other people when necessary



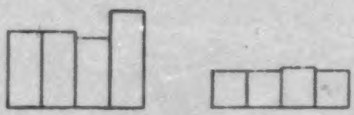
18. readiness to learn about something completely different



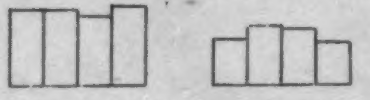
19. understanding the relationship between parts (subject areas) of ME



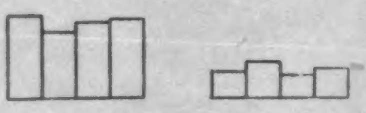
20. readiness to question accepted ideas



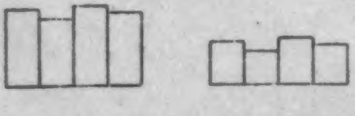
21. ability to think three dimensionally



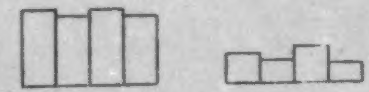
22. practical experience of engineering practice



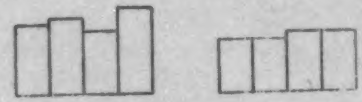
23. tolerance of other people



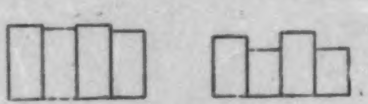
24. sensitivity to people/situations



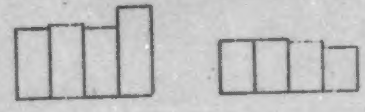
25. capacity for dedication to tasks



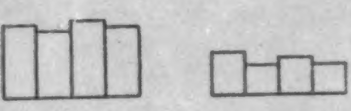
26. recognition of own limitations



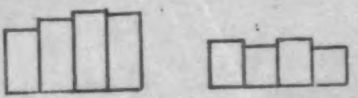
27. readiness to explore further some area already studied



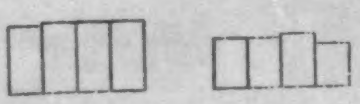
28. awareness of general human problems



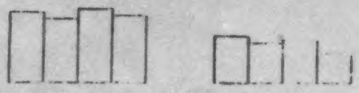
29. understanding of ME in relation to other subjects/areas



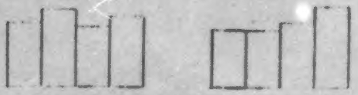
30. awareness of existing rules/norms/limits



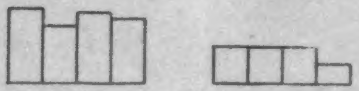
31. sense of ambition
(personal expectations)



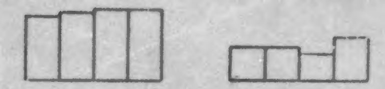
32. interest in engineering design



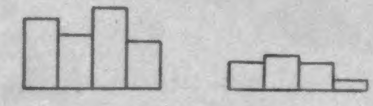
33. understanding of
industrial relations



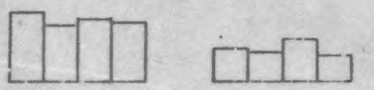
34. interest in industrial
scene in general



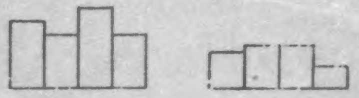
35. preparation for taking
managerial decisions



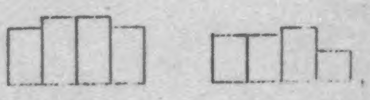
36. willingness to share
concerns of others



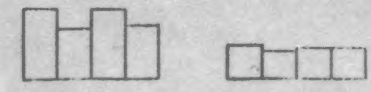
37. knowledge of
management techniques



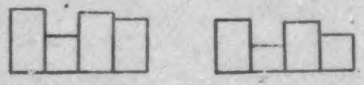
38. capacity for getting rapid results



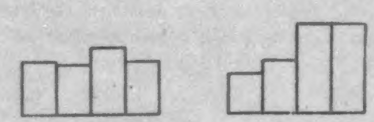
39. personal security



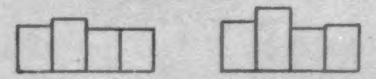
40. commitment to personal
advancement



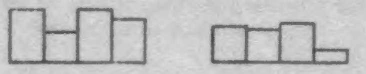
41. experience of computer use



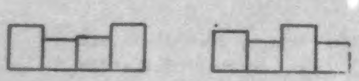
42. interest in a specific field in ME



43. preference for uncertainty/
adventure/chance



44. preference for regulated lifestyle



AIMS QUESTIONNAIRE

Aims of a Mechanical Engineering Education

Dear

Aims of an Undergraduate Education in Mechanical Engineering

As a result of the feedback that I received on my Informal Report to mechanical engineering staff which you received earlier in the year I have planned a small survey on the aims of undergraduate mechanical engineering education. The purpose of this survey, which is being conducted with both staff and students in mechanical engineering at Strathclyde and Heriot-Watt, is to look rather more systematically at the various views on the more general aims of the undergraduate course. I would like to ask you for your assistance in this task.

A list of aims had been assembled by Mr. Koc before he had to retire from the project and he had completed a small survey of Heriot-Watt students. I am using the same list for the sake of consistency and comparability. I would like you to look at the given aims and to rate each one in terms of (a) the extent to which you think them important and (b) the extent to which you think the course/university does in fact help develop them. You may find some of the aims ambiguous or not as clear as you may wish. I ask you to bear with this and recognise that this questionnaire is a fairly blunt measure : there is an opportunity for you to expand or qualify your ratings over the page.

I hope you can find time to do this in the next few days. It should take you no longer than 10 - 15 minutes. I would like you to reply by 31st October.

Your name will not be associated with your comments in any way and I hope you will feel free to express yourself as fully and directly as you wish. I will send you details of the analysis of results as soon as it is ready.

I look forward to receiving your views.

Yours sincerely,

Dave Boud

Please examine the following list and answer the
two questions asked by circling the appropriate response from
0 = not at all, to 3 great extent

		do you think this is important ?				you think the course/univers does, in fact, help develop th			
1	knowledge of particular facts and terminology of ME	0	1	2	3	0	1	2	3
2	engineering commonsense	0	1	2	3	0	1	2	3
3	understanding of general principles/theory of ME	0	1	2	3	0	1	2	3
4	competence in problem analysis and calculation	0	1	2	3	0	1	2	3
5	understanding of ME in relation to other subjects/areas	0	1	2	3	0	1	2	3
6	interest in a specific field in ME	0	1	2	3	0	1	2	3
7	interest in engineering design	0	1	2	3	0	1	2	3
8	understanding the relationship between parts (subject areas) of ME	0	1	2	3	0	1	2	3
9	experience of computer use	0	1	2	3	0	1	2	3
10	ability to think three dimensionally	0	1	2	3	0	1	2	3
11	practical experience of engineering procedures	0	1	2	3	0	1	2	3
12	understanding of industrial relations	0	1	2	3	0	1	2	3
13	knowledge of management techniques	0	1	2	3	0	1	2	3
14	preparation for taking managerial decisions	0	1	2	3	0	1	2	3
15	interest in industrial scene in general	0	1	2	3	0	1	2	3
16	ability to comprehend new material accurately and quickly	0	1	2	3	0	1	2	3
17	ability to evaluate material (to use evidence)	0	1	2	3	0	1	2	3
18	ability to communicate in writing	0	1	2	3	0	1	2	3
19	ability to be communicative, articulate, in speech	0	1	2	3	0	1	2	3
20	ability to use/apply knowledge	0	1	2	3	0	1	2	3
21	readiness to question accepted ideas	0	1	2	3	0	1	2	3
22	readiness to learn about something completely different	0	1	2	3	0	1	2	3
23	readiness to explore further some area already studied	0	1	2	3	0	1	2	3
24	ability to co-operate with others	0	1	2	3	0	1	2	3
25	willingness to take responsibility	0	1	2	3	0	1	2	3
26	ability to organise other people when necessary	0	1	2	3	0	1	2	3
27	capacity for getting rapid results	0	1	2	3	0	1	2	3
28	capacity for dedication to tasks	0	1	2	3	0	1	2	3
29	ability to cope with unfamiliar situations	0	1	2	3	0	1	2	3
30	sensitivity to people/situations	0	1	2	3	0	1	2	3
31	ability to keep going when things go wrong	0	1	2	3	0	1	2	3
32	sense of ambition (personal expectations)	0	1	2	3	0	1	2	3
33	recognition of own limitations	0	1	2	3	0	1	2	3
34	tolerance of other people	0	1	2	3	0	1	2	3
35	flexibility (ability to try many alternatives)	0	1	2	3	0	1	2	3
36	ability to understand/consider contrary opinions	0	1	2	3	0	1	2	3
37	willingness to share concerns of others	0	1	2	3	0	1	2	3
38	personal security	0	1	2	3	0	1	2	3
39	preference for regulated life style	0	1	2	3	0	1	2	3
40	preference for uncertainty/adventure/chance	0	1	2	3	0	1	2	3
41	awareness of general human problems	0	1	2	3	0	1	2	3
42	commitment to personal advancement	0	1	2	3	0	1	2	3
43	awareness of existing rules/norms/limits	0	1	2	3	0	1	2	3
44	realism	0	1	2	3	0	1	2	3

Please look at your ratings briefly again. Write down the number of any aim that you would like to mention and give your further comments.

I would like you to pay particular attention to aims that you have rated low in the second column, but which you think are important.

Other Comments about the questionnaire

or the Project itself

THE FIRST YEAR ENGINEERING COURSE AT STRATHCLYDE : AN EVALUATION

This section will describe the background and development of the newly established first year mechanical engineering course (Engineering 16.151) at the University of Strathclyde which began in October 1975. The aim of this section is to focus on two factors. Firstly, on the stages of development of the course, how it evolved during the planning stage and the factors that most influenced it. Secondly, on the reactions of the students to the course. The reactions of the teaching staff are included at various points but as this is primarily intended as a discussion document for them this has not been the main focus. It is hoped that this will help facilitate discussions about the future development of the course.

The component of the course called skills tutorials has been subject to a more detailed study and discussion of the development and practice of these appears in the following section.

Background to the course

It has been traditional in Scottish universities for students to spend their first year of study pursuing a broad range of subjects before specialising in their particular degree subjects in the later years of the course. In engineering students would spend their first year studying Mathematics, Physics and Chemistry taught by staff from those departments, not starting any engineering subjects or meeting engineering staff until the second year. The only exception to this is Engineering Drawing which has been taken for some time in the first year.

There had been dissatisfaction for some time amongst both staff and students concerning this arrangement. Students were disappointed that when they arrived at the university with the intention of taking engineering they were faced with a year's delay whilst they pursued what they regarded as 'school subjects'. Engineering staff were sympathetic to this view and whilst they appreciated the importance of this arrangement in providing a firm scientific background they also wished for some contact with what they regarded as 'their' students.

For twelve years or more discussions had been taking place amongst the mechanical engineering departments with a view to teaching at least part of the first year course from their own resources. Various proposals were made which eventually culminated in a proposal to the university that the Mechanical Engineering departments should use the time that students normally spent in Physics and Chemistry to teach those parts of those subjects that were directly relevant to engineering and to commence the engineering course at an earlier stage. This proposal was based on the two aims of the desire to teach basic physical principles in the form relevant to engineering and to establish closer contact with students who would subsequently go on to study for a degree in mechanical engineering.

This proposal was unsuccessful on at least two grounds. Firstly, it was by no means agreed that it was appropriate for the engineers to teach all the basic science themselves, indeed, some members of the engineering staff felt that Physics was most suitably taught by physicists and that it was an advantage to students to see how the physicist approached problems. Secondly, it would severely cut the student numbers in the Physics and Chemistry departments and thus would cause problems to do with staff load in these departments.

The engineers had to think again about the first year course. Their aims remained unchanged but approximately two years later they submitted a less ambitious proposal which would allow Physics and Chemistry to retain part of their first year courses whilst introducing a component of engineering. The timing and content of this proposal were more auspicious. The principle of applied science departments teaching more of the basic courses had started to be established in other Schools in the University and the number of courses that the mechanical engineering departments taught on a service basis for other departments had declined. The changes in the staff loading factors in the various departments would be less drastic and it was easier to convince the university on educational grounds of the merits of a modest proposal.

The course that was agreed involved a reduction by about half of the Physics and Chemistry courses and the substitution in the time saved of a course in Engineering taught by departments in the Mechanical Engineering Group. In detail the engineers took over most of the mechanics and heat parts of the physics syllabus and included these using an engineering approach to the subject in a course of basic statics, dynamics, thermodynamics and fluid mechanics called Engineering 16.151. This course was taken in full by all mechanical and production engineering students, and in part by students of environmental and chemical engineering and naval architecture.

Course design (Engineering 16.151)

The preceding description presents the events that occurred external to the discussions within the Mechanical Engineering Group. In parallel with the deliberations of university committees the proposals for the first year were the subject of much internal debate. As different parties in the debate have different perspectives their accounts vary, but the main aspects of it were as follows, not in chronological sequence.

One of the original ideas was that the first year class would be conducted by the three professors who headed the Mechanics of Materials, Dynamics and Control and Thermodynamics and Fluid Mechanics Departments. They would give 'prestige' lectures to the entire first year class which would enable the students to meet the professors right from the start of the course and would present the engineering approach to the basic subjects. Provisional syllabuses were drawn up by the heads of departments with varying degrees of consultation amongst staff in their departments and these were discussed amongst the professors.

Lectures

It emerged that not all three professors were equally committed to the idea of lecturing to the first year and eventually only one head of department remained as a lecturer on the course. At least one of the departments thought it desirable that the total class be split in half. This would be in line with the traditional practice in later years of the course where classes were divided in two when the number of students reached a certain figure. The idea behind the splitting proposal is that it is easier to lecture to a class of forty, say, than one of eighty, that the atmosphere is more intimate and that students have greater opportunity to ask questions. The implication of the splitting arrangement was that not all students would be able to be in the class of each professor unless an alternative time were arranged for a repeat lecture and the professors were willing to lecture twice on each topic. This was not acceptable but a split class was agreed.

It was agreed that in order to maintain parity between the three departments each would contribute one third of the lectures, that is, one per week. A decision then had to be made on the best distribution of these three components in the course. There were two distinct standpoints. One was that each component of the course should have one lecture per week devoted to it so that the three ran in parallel. This had the suggested advantages of convenience of timetabling, the independence of the three components, that a student will miss less of a given course if he is absent, that a student has more time to assimilate the ideas, and that there is a parity of examining, that is, all courses can be equally examined at the same time each term. The other point of view was that the components should be presented sequentially with the students taking, say, statics at three lectures per week, then dynamics, and so on in a block arrangement. The advantages claimed for this approach were that students only needed to assimilate one subject out of three at a time, that a closer relationship could be established between staff and students if the course were more intensive, that it was easier for staff to do all their teaching in one burst, that it would be simpler to integrate the subjects if each had been studied in turn and that each lecturer would know more clearly what each student had covered.

Eventually a compromise was reached. Each department in turn would give four consecutive lectures; this would cover the first four weeks and after that the three subjects would be taught in parallel at one lecture per week for each. The rationale for this agreement was that the very basic principles of each component of the course would be presented by lecturers who would integrate very closely with each other to save overlap at the beginning. Otherwise, the situation might obtain where students were presented with repetitions of Newton's laws in the first few weeks.

Tutorials

In addition to the lectures there was a tutorial and laboratory component to the engineering course. The planning of the tutorials consisted of the transfer of the system that was in use in the second and third years to the first year. The tutorial system worked as follows. A one hour tutorial was scheduled once every two weeks for each student. The tutorial would consist of half the number of students meeting in the lecture room on alternate weeks although students could attend on the 'in-between' weeks on a voluntary basis, so that in the split class there would be about thirty students in each tutorial, and present in the class would be the three lecturers who contributed to that section. That is, one quarter of the total number of students in the class would meet three lecturers for one hour per fortnight. Problems sheets relating to the subject matter covered in the lectures would be given to students and they would be expected to work through these on their own and bring any difficulties that they experienced to the staff in the tutorials. The same lecture theatre would be used as for lectures. The structure of the tutorial would be entirely informal; the lecturers would be present to answer questions on an individual basis or with a collection of students. The scene in a typical tutorial would be for about thirty students to be sitting at their desks, some on their own, some discussing with one or two other students; the members of staff would be talking to the students and assisting them with difficulties that they would present from the problems sheets. It was up to the students what problems they would tackle and they would be provided with the numerical answers but not the method of solution so that they could check their own work. Although suggestions might be made in lectures about what problems the students should tackle there was no way of monitoring how any student or group of students was progressing or how many problems they were attempting.

Laboratories

The laboratory component was divided amongst four departments for the mechanical and production engineering students, the three departments already referred to plus the Department of Production Management and Manufacturing Technology. The other students would take some of these laboratory classes plus others in their own departments. The laboratory classes were scheduled for Monday afternoons to follow the tutorial period and each lasted for two and a half hours. Students were to spend two sessions (afternoons) with Dynamics and Control, and Thermodynamics and Fluid Mechanics respectively and three sessions with PMMT and Mechanics of Materials. The rationale for this was that the Production department were not contributing to the rest of the course and could therefore have more time in the laboratory and the Mechanics of Materials laboratory would include a one hour skills tutorial which would be contributed to by the other three departments.[1] Each part of the laboratory course would be self-contained and the responsibility of the department concerned. No attempt at liason or co-ordination on the laboratory components was made except for agreement on the policy that the laboratories should be interesting and stimulating and aim to illustrate some of the practical aspects of engineering.

Staffing

The course which emerged involved six people giving lectures throughout the year and conducting tutorials; at least another six involved in laboratory teaching (not including staff outwith

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[1] for further details see the Skills Tutorial case study

the MEG) and, in addition, four more who were not contributing in other ways, in the skills tutorials, all these from four departments. A class 'registrar' who was one of the lecturers was appointed to the class to be responsible for timetabling and organisational arrangements, but no-one acted as co-ordinator for all these various activities. Although the class registrar did perform parts of this function with regard to lectures and tutorials on an informal basis, no-one appeared to know what was occurring in all the laboratory classes or was responsible for bringing together all the staff involved in the Engineering 16.151 course.

Objectives

Agreement had been reached on the overall form and structure of the course. The aims had been accepted. These were that the course should provide a foundation in aspects of mechanics and certain other subjects which would be studied more intensively in following years. The course should stimulate interest, introduce students to the 'engineering approach' to problem solving and illustrate basic principles by reference to many applications. Coverage of a great range of subject matter was less important than that the students had a very firm grasp of the basic principles.

Teaching strategies

Differences of opinion remained on the approach to the subject. In the earlier stages of the discussion there emerged two strategies that were propounded by different lecturers. The first view started from the premise that students should learn engineering by starting with basic scientific principles, gaining a thorough grasp of these and then look at some real world applications of the principles. This is the generally accepted strategy in second and third year courses; starting from principles and moving towards applications. It can be termed the principle-centred approach. The other view was based on the idea that the first is not very motivating to students and that it looks at problems in an artificial way. Engineers start with problems and then look for the principles, "the way the engineer has to work is that a problem is thrown at him which he has to solve by hook or by crook, it doesn't have wee labels all over it saying 'Newton's First Law'". This approach proposes a course that presents a series of carefully chosen, real engineering problems, each of which illustrates certain scientific principles. It can be termed the problem-centred approach. It involves a complete redesign of the introductory course as the second year courses are not constructed along these lines. The two approaches are contrasted as follows :

Principle-centred approach	Problem-centred approach
principles ⟶ applications Advantages thorough grounding in fundamentals logical framework teaching strategy well established and continued in later years of the course	problems ⟶ principles Advantages demonstrates relevance of principles inductive framework more motivating to students closer to engineering practice

Although discussion in the early stages was focussed on either persuading the other party of the merits of the alternative approach or reconciling the two approaches, it was not necessary for any decision to be reached about this. In practice, each pair of lecturers could decide on their own strategy without reference to the other components. The only place where this was not possible was in the initial four weeks where, through the voluntary collaboration of the staff from the three departments providing each component, the integration of the three components forced a fairly common approach. As it developed the proponents of the problem-centred approach did accept that the principle-centred strategy was appropriate for tne first few weeks after which they could continue in their own way.

The reality of the situation was rather more complicated as not all the lecturers would agree on which of the two approaches they were using. Some of those whose lectures appeared to be principle-centred and who were associated with the description that they were "bringing down the second year course to first year", did espouse a problem-centred strategy. Confusion was added to the matter when the terms 'engineering science' and 'engineering approaches' were used, for whilst the engineering science position is normally regarded to be similar to the 'from principles to application', principle-centred approach, those who did adopt a principle-centred lecture course would prefer to be described as using an engineering approach to the subject matter.

The description and discussion has not been restricted to the course itself as very important decisions which have crucially moulded the course have been made on what can be loosely called non-educational factors. The 'political' climate in the mechanical engineering departments has emerged as one of the forces which influenced the format and structure of the course and any discussion which ignored this would present a very incomplete picture. The inter-play between 'political' and educational factors and the sometimes hazy distinction between the two are important in any course development process but, because of the sensitive nature of the problems and the well documented tendency of the protagonists in any given context to not confirm, or deny the description that is produced, many descriptions of course planning discreetly ignore what may be regarded as essential factors. Sheldrake has drawn attention to the 'two realms of discourse' that exist in discussions of course development, that discussions take place in terms of internal political reality but are legitimised to external audiences as discussions of educational factors.[1] This phenomenon was observed clearly in the first year course planning.

The course and evaluation

Engineering 16.151 started in the Autumn Term 1975 with 54 mechanical engineering and 10 production engineering students. Greater or lesser parts of the course were taken in the same classes by students doing chemical engineering (32), environmental engineering (11) and naval architecture (17). All groups took statics, dynamics and the tutorials.

I was invited to assist the staff concerned in monitoring the course and I observed lectures, tutorials and laboratory classes and interviewed staff and students throughout the year. Many of the problems raised by students were reported to the staff during the year so that remedial action, if necessary, might be taken. The evaluation, apart from the skills tutorials, was not an intensive one and probably around one hour per week was devoted to it. In addition, I spent two hours per week on average on skills tutorials, in discussions, observations and evaluation.

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[1] P. Sheldrake "The Politics of the Curriculum" in W. A. Verreck (ed) 'Methodological Problems in Research and Development in Higher Education', Amsterdam : Swets and Zeitlinger BV, 1974

The staff appeared to react favourably to my role and I was invited at their suggestion to prepare and administer a questionnaire to students to gather their reactions on a more systematic basis. A questionnaire was drafted which aimed to probe some of the problem areas that had emerged in discussions with staff and students, to cover topics on which the staff wanted more information, and give students an opportunity to raise any other issues that they felt concerned about. It included a mixture of fixed-response and open-ended questions. The draft was circulated to staff who took a great interest and made comments on it and suggested additional items for inclusion. A copy is included on P.73 .

Student reactions

The questionnaire was distributed to all students attending the engineering classes on the final Wednesday of the Spring term, unfortunately only a small section of the class was present. The remainder were distributed during the first week of the Summer term. In total, 49 students from all courses responded and these included 40 mechanical engineering students who had been particularly encouraged by their lecturers to complete and return the questionnaire.[1] This is 74% of the total first year class of mechanical engineers. The numerical results will only refer to the mechanical engineers, but comments drawn from others will be included if they represent views also held by mechanical engineering students.

The responses were sorted into those that took lectures in the two rooms, M.328 and M.329, to check to see if there were any systematic differences in the responses of those students who had a different set of lecturers for the course. The differences were so slight that the two parts of the class are taken together in the following analysis.

The following section is based on the questionnaire results considered in conjunction with information obtained from interviews with students throughout the year. The limitations of both questionnaire and interview data should be borne in mind. In questionnaires it is only possible to ask very simple questions and get simple replies ; some of the most important issues may be such that they cannot be addressed directly in a questionnaire and the opinion of students may only be inferred from their responses; students are only in possessions of limited information and limited experience and it is unreliable, although sometimes still desirable, to ask questions about alternative activities to those that they have experienced; and finally, students are unwilling to expose themselves a great deal on sensitive matters even under assurances of confidentiality. In interview it is possible to ask more complicated and sensitive questions and to follow up replies with further questions on the spot. It is not possible in a large sample to cover as many students and the data elicited may reflect the unconscious biasses of the interviewer, and be less available for open scrutiny.

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[1] Emphasis has been placed on the reactions of mechanical engineering students as the Mechanical Engineering course is the main focus of the other project activities.

The aim of this section is to provide a basis for discussion of the course amongst staff[1] and the responses of staff are not included.

Most of the students had come directly from school, 12 from the 5th year and 23 from the 6th year, a total of 35. Two had come from a technical or further education college and 3 were in industry before coming to university. Two of those from school were repeating the first year course.

Only 8 students had any experience in industry related to engineering although another 9 had had some kind of work experience. Half the sample, 20, had had no experience of work at all.

What influenced them to take engineering at the university ?

The most common influence was through direct personal contact with engineers; 21 students thought this was the main influence on them. Out of these, 11 knew engineers in their family. Three said that experience in industry had influenced them. Of the others, the main influences were from reading (17), from school teachers (9) and from parents (6). Some students had multiple influences.

Other factors mentioned were interests in things mechanical (2), a feeling that prospects in engineering were good (1), and most commonly from the fact of being good at 'engineering type' subjects at school (5) : "It simply emerged as a 'natural choice' through the years at school". All but 6 students out of 40 had made mechanical engineering their first choice of subject to study.

What do they see as the aims of the course ?

Students were asked to rate each of six items in terms of the degree of importance attached to each in the course. As can be seen in the table, the aims rated in terms of the position of mode from 'major aim' to 'not an aim' were as follows :

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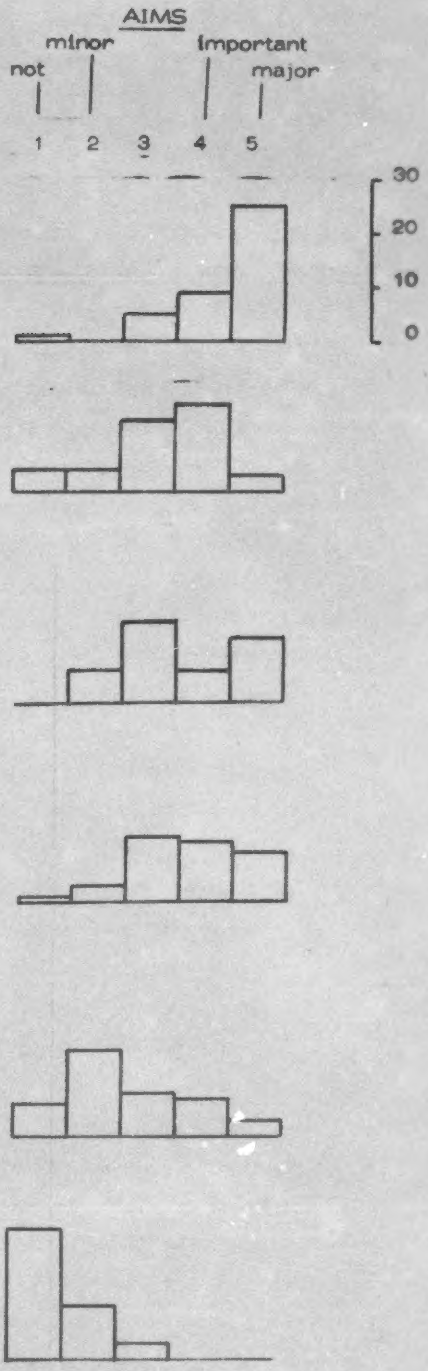
[1] It is not in keeping with the norms of the departments to involve students in such discussions.



1. to teach basic principles of mechanics, etc.

2. to foster interest in mechanical engineering

3. to present a unified approach to basic engineering

4. to show the practical application of basic theory

5. to demonstrate what mechanical engineers do

6. to encourage one to become committed to being a mechanical engineer

The ratings indicate the aims of the staff are perceived to be important in the course. These last two were seen to be either very minor aims or not aims of the course at all in the view of most students. Most of the comments added by the students reinforce or reiterate their view of the aims given, however some comments referred particularly to the need for the course to show more applications and be less abstract, "it seems to be to get us to think of everything as a simplified model and then dive into mathematics".

How well prepared for the engineering course were the students ?

Two aspects of the course were particularly mentioned by students, in each they thought they had been particularly poorly prepared or the engineering lecturers assumed they knew more than they did know. These were :

1. Assumption of basic engineering terminology, "they assumed that you knew all the technical patter". As most of the students had had little or no contact with engineering before the university, this assumption was not valid.

2. Assumption that everyone was proficient in mathematics. Students complained that the engineering course, especially Dynamics, took for granted that they were skilled in the use of calculus, particularly forms of integration. The dynamics lecturers assumed knowledge of integration that had not been covered by students either in Highers, or up until that stage in the parallel Mathematics course. The parts of the course particularly affected were moments of inertia and rotational motion. This part not only assumed knowledge of mathematics but that students understood the concepts of moments, torque (which was a completely new word to some students), and centrifugal force.

No students expressed difficulties of preknowledge for the Statics section, and only one found problems in this regard in Thermodynamics and Fluids.

One of the difficulties of analysing students' lack of preknowledge in this section is that they have not been very specific. In talking to students I get the impression that some of them are still experiencing great difficulty with things that the staff assume they should have met before, but they have difficulty in articulating this in detail as they 'don't know what they don't know'.

The lecture course

Students were asked if they thought that the contents of any of the lecture courses were repetitions of school physics, extensions of it, or completely new. Very few (3) thought that any of the courses were an unnecessary repetition. The responses were :

	Statics	Dynamics	Thermo-dynamics
An unnecessary repetition school (H grade) physics	3	1	0
An extension of school (H grade) physics	26	18	7
Almost all new material	10	17	30
No response	1	4	3

At least six students had taken H grade in Engineering Science and these at least were familiar with the terminology. They felt that the course was an extension of this material and that they were well fitted to start this course.

They were asked about the pace of the courses. The replies were :

	Statics	Dynamics	Thermo-dynamics
Too fast	1	18	9
About right	35	22	31
Too slow	3	0	0
No response	1	0	0

Students in both rooms felt that Dynamics was rather on the fast side, but this was quite marked for the group in M.328, the majority of whom felt the course to be too fast. Many of the problems of the pace of the Dynamics course seem to stem from the assumptions that staff are making about what the students already know about mathematics and aspects of physics.

Despite the fact that most of the Thermodynamics and Fluids course is new to the students there were comments from one section that this was "very dry", "boring", or, "something was lacking". It is not possible to pin down exactly what students mean by these statements as their other comments indicate that they appreciate the importance of this part of the course.

The lectures in the engineering course are generally praised as being of a more consistently high standard than those in other courses that they take, ie. physics and chemistry.

Students were questioned on two topics that had been the subject of some debate amongst the staff. These were the arrangement or sequencing of the different aspects of engineering, and on the use of lecture notes. They were presented with the three options that had been discussed by the staff and their views are as follows :

I would prefer one lecturer at a time for the whole engineering course	3
I prefer three parallel sections with three lecturers	19
I prefer the present arrangement, i.e. starting with one course and then splitting into three	18

In retrospect, this was a badly put question as it is commonly found that students tend to prefer those options of which they have some direct personal experience.

There were a few comments that these were not the only options and some would have preferred different times to have been spent on the three sections in proportion to the difficulty of each.

With regard to printed notes, the student response was very favourable. Thirty-three found them helpful, 6 were not sure and only 1 thought them unhelpful. When asked if there were any parts of the course where they would find printed notes helpful 16 students mentioned Dynamics or particular aspects of dynamics. This seemed to reflect on those parts that they had found most difficulty with, that is, moments of inertia, rotational balancing, etc. An other request was for worked examples to be provided for all three courses. A criticism was made of lecturers who almost dictate their notes slowly on the blackboard.

Tutorials

Students were asked to estimate the proportion of tutorials that they had attended throughout the year.

Almost all/all	21
More than two-thirds	12
More than half	6
More than one quarter	1
Very few	0

This should be compared to the actual attendance at tutorials which averages at around two-thirds of those students expected to attend throughout the year.

They were asked if they had any particular reasons for not regularly attending tutorials. Only five replies were given to this, but those that did reply indicated that the reason they do not attend was because they think they will get little benefit from them;

they quote examples of tutors not explaining problems in ways that they can understand, of not attending when they have not completed examples sheets, of falling behind with the sheets and being inhibited about asking questions about early sheets. One student mentioned that," I spend most of my time at tutorials discussing anything other than engineering, as do my friends". This is echoed by another student who comments on 'too much of a relaxed atmosphere'. A few comments are made about tutorials 'not well enough organised'.

As some dissatisfaction with tutorials was found during interviews with students an attempt was made to clarify their views in the questionnaire. Students were provided with a list of fourteen statements with which they were invited to agree or disagree. These are listed in the order of strength of agreement or disagreement (statements marked thus * are reversed for sake of easy comparison).

1. I would like specific problems set for specific times (33 agree, 7 disagree)
2. I seldom ask questions about the lectures (31, 4)
3. I like the presence of all three lecturers (29, 10)
4. I wish there was more pressure on me to work (29, 11)
5. The problems on the sheets are not too tough* (28, 10)
6. Tutorials in other subjects should not be like engineering tutorials* (26, 11)
7. I wish the problems could be properly marked (26, 11)
8. I do not feel rather inhibited about asking for help* (26, 12)
9. I wish they could go through problems on the board (25, 13)
10. It does not take a long time to get help in the class* (22, 15)
11. I do get as much help as I would like from them* (22, 16)
12. I would not like smaller groups with one member of staff* (21, 18)
13. There should be more time for tutorials (20, 18)
14. The class is too big (19, 19)

It is important to note that there is a considerable disagreement in response to all but the first two statements. This points to a wide variety of needs amongst the students in the class and to the view that the present arrangement does not suit them all or even the great majority.

When viewed in conjunction with the students' views in interviews it is clear that a majority of them do not like what they see to be the very casual approach to tutorials in the engineering class, an extreme view being, "A firmer hand should be taken in tutorials, most people are lazy and unless forced they will do nothing."
In physics and mathematics they are used to pressure to complete problems, the tutor going through tutorial problems on the blackboard and to the tutor marking their problems for them. It is also clear that students see 'tutorials' as example classes and do not use them as opportunities to ask questions about the lectures. The potential flexibility that exists in the tutorial when student and tutor talk individually is not utilised by the students - they tend to concentrate almost exclusively on getting help

with solving problems.

Laboratory classes

Mechanical engineering students take laboratory classes in four departments : Mechanics of Materials, Dynamics and Control, Thermodynamics and the Mechanics of Fluids, and Production Management and Manufacturing Technology. One of the declared aims of the laboratory class was to stimulate the students and arouse interest in the practical and experimental aspects of engineering. Students were asked which experiments they found the most interesting and which the most uninteresting : they had to write in the names of the experiments from memory :

	Interesting	Uninteresting
Mechanics of Materials		
Lift acceleration	14	2
The safety of handrails	7	15
Stiffness of structures	6	4
Dynamics		
Pendulum	3	22
Friction	6	18
Thermodynamics and Fluids		
Temperature measurement	5	3
Fluid Mechanics : Jet propulsion	16	1
Production		
Engineering metrology		
- components/tolerances	3	1
- washing machine motor	1	7
Production technology		
- machine shop tour	1	2
- machine tools, forming, cutting	12	4
Production management	10	1

Comments were made that applied to several of the experiments in different departments. The first was that the students would like to have taken a more active role in some of the experiments : "the laboratories seem to entail standing and watching the demonstrator do the experiment. This means we get bored and uninterested.", and for some the groups are too large : "one or two do the experiments, the rest just get a copy of the results". The second was that they were very rushed : "there was not enough time to do a decent job", "not enough time given to plan out the experiment ourselves. Just told what to do or have it done for us.". The third comment was that the laboratories were unrelated to the rest of the course and just consisted of isolated experiments not linked to each other or to the lectures.

Did the course stimulate students to consult books ?

Two books were recommended for the course. Students were encouraged to buy 'How Things Work, volumes I and II' as a background to the present course, and 'Applied Heat for Engineers' which they would use in later courses following the Thermodynamics lectures.

Twenty-six out of 40 students possessed one or other volume of 'How Things Work' but few had read much of it. Twelve students had not read any part of it at all and 14 said they had referred to it very occasionally; 14 had read parts of it sometimes and only 4 had consulted it very often. With regard to 'Applied Heat for Engineers', only 14 students said they had referred to it.

Students who had consulted the recommended books were not very satisfied with them as textbooks for the course (this does not apply to 'Applied Heat for Engineers'). They wanted books which would help them with the course, "I think the greatest aid would be a textbook covering each of the three subjects to a certain degree of detail". They felt that they had nothing to refer to when they were stuck except Highers textbooks and school notes which in many instances did not go far enough and they would have appreciated an alternative explanation to their lecture notes when they had difficulties.

The usage of other books was extremely low if students' Highers textbooks are excluded. Eight students mentioned the physics text, 'College Physics' and the only other book that was referred to by more than one student was, 'Teach Yourself Dynamics', which had been read by two.

The question, "Has the course encouraged you to read any other books?", received no response from any student.

Staff-student relations

In later years of the mechanical engineering course some students felt that the contact between staff and students was minimal. Two questions were asked on this theme of the first year :

Have you ever been to see a member of staff in his office (apart from your counsellor)	YES	12
	NO	28
Do you feel there is sufficient contact with staff ?	YES	23
	NO	16

Commitment to engineering

One of the subsidiary aims of the course had been to encourage students' commitment to engineering through presenting stimulating material and interesting content. Although this was not perceived to be an aim by the students (see aims rating) they did report the following :

As a result of the course I have become more committed to becoming a professional engineer	AGREE	15
	NOT SURE	21
	DISAGREE	4

Other concerns of students

Not unnaturally, the other aspect of the course which mainly concerned the students were the examinations. Some were surprised that the exam questions were in a different format to the tutorial questions and would "appreciate some experimental exam papers as would be expected in the first year degree exams". At the more detailed level some complained that the second term Dynamics exam covered almost exclusively first term work, "are they saying that only one lecture was worth attending in term two?", not realising that this had been done in response to their worries about mathematical pre-knowledge.

One of the students who was taking the first year again said how pleased he was to do engineering in the first year course, "I found this first year course much more gratifying as when you come from school you arrive at university and find there is no engineering subject. It's a bit disheartening. This year's course has been a lot better than last because when you are doing the engineering you feel you are getting nearer the BSc". However, of those students who are there for the first time and who can make no such comparison, some are critical of the overall approach, "There is not enough about the practical applications of engineering. It's all theory work and not being put to any use at the moment.", and point out firmly, "I can't see how what I am doing is going to help me when or if I graduate."

ENGINEERING 16.151

As you know, the present first-year course in engineering is being run for the first time this year. The staff concerned are particularly interested to know what your impressions are of this course so that improvements can be made for the future. This questionnaire is designed to give you an opportunity to express your views on most aspects of the course. It cannot cover everything and I would like you to feel free to make additional comments wherever you feel them to be needed. If you choose to add your name your views will remain completely confidential - none of the staff responsible for teaching or examining will be able to associate your name with your comments. Please be as frank as possible.

Dave Boud, Leverhulme Project

Name (optional) ____________________

Course ____________________

I attend lectures in M.328 ___

M.329 ___

I came to Strathclyde :

- direct from 5th year at school ___
- direct from 6th year at school ___
- from a technical/F.E.college ___
- from industry ___
- other (please specify) ____________

____

I have :

- had some experience in industry related to engineering ___
- had work experience not related to engineering ___
- not had any work experience ___

What were the main influences on you taking engineering at university ? (You can tick more than one)

- From experience of industry ___
- From knowing engineer(s) (a) in the family ___
  - (b) not in the family ___
- From schoolteacher(s) ___
- From parents ___
- From reading ___
- Other (please specify) ____________________

____

____

Mechanical Engineering WAS/WAS NOT my first choice of subject.

Aims of the course

The following are some aims that have been proposed for the first year engineering course. Please indicate the extent to which you think that they are in fact aims of the present course, that is, to what extent is the course concerned with the following :

	not really an aim	a minor aim	an aim	important aim	major aim
to foster interest in mechanical engineering	1	2	3	4	5
to teach basic principles of mechanics, etc.	1	2	3	4	5
to present a unified approach to basic engineering	1	2	3	4	5
to show the practical applications of basic theory	1	2	3	4	5
to demonstrate what mechanical engineers do	1	2	3	4	5
to encourage one to become committed to being a mechanical engineer	1	2	3	4	5

Lectures

On reflection, were there any topics in which you now feel you were not adequately prepared for before the course ? That is, did the course assume anything that you had not covered before ?

Do you consider the contents of any of the lecture courses to be

	Statics	Dynamics	Thermo. & Fluids
An unnecessary repetition of school (H grade) physics			
An extension of school (H grade) physics			
Almost all new material			

Comments

Do you consider the pace of lectures to be

	Statics	Dynamics	Thermo. & Fluids
Too fast			
About right			
Too slow			

At the beginning of the course the engineering lectures we gave all three lectures in a week, now lectures are given parallel. How do you find this arrangement ?

I would prefer one lecturer at a time for the whole en

I prefer three parallel sections with three lecturers

I prefer the present arrangement, ie, starting with one course and then splitting into three

Other suggestions - please specify

Did you find the use of printed lecture notes in the Thermodynamics and Fluid Mechanics part of the course to be :

Are there any parts of other courses where you would fin

Tutorials

Taking the year as a whole, what proportion of engineering tutorials would you estimate that you have attended ?

Al

M

M

M

V

Are there any particular reasons for not attending engin

The following are some statements made about engineer tutorials. Please indicate if you agree or disagree with

I do not get as much help as I would like from them

I wish they would go through problems on the board

Tutorials in other subjects should be like engineeri

The class is too big

I would like a smaller group with one member of st

I would like specific problems set for specific time

I wish the problems could be properly marked

It takes a long time to get help in the class

I like the presence of all three lecturers

I seldom ask questions about the lectures

I feel rather inhibited about asking for help

There should be more time for tutorials

The problems on the sheets are too tough

I wish there was more pressure on me to work

n proposed for the first year engineering
ch you think that they are in fact aims of the
the course concerned with the following :

	not really an aim	a minor aim	an aim	imp-ortant aim	major aim
ring	1	2	3	4	5
ic.	1	2	3	4	5
gineering	1	2	3	4	5
ic theory	1	2	3	4	5
rs do	1	2	3	4	5
o being	1	2	3	4	5

which you now feel you were not adequately
, did the course assume anything that you

___

___

___

lecture courses to be

	Statics	Dynamics	Thermo. & Fluids
H grade) physics			
ics			

___

___

e

Statics	Dynamics	Thermo. & Fluids

P

At the beginning of the course the engineering lectures were arranged so that one lecturer gave all three lectures in a week, now lectures are given by three lecturers per week in parallel. How do you find this arrangement ?

I would prefer one lecturer at a time for the whole engineering course	___
I prefer three parallel sections with three lecturers	___
I prefer the present arrangement, ie, starting with one course and then splitting into three	___

Other suggestions – please specify ___

___

Did you find the use of printed lecture notes in the Thermodynamics and Fluid Mechanics part of the course to be :	
Helpful	___
Not sure	___
Unhelpful	___

Are there any parts of other courses where you would find printed notes helpful ?

___

Tutorials

Taking the year as a whole, what proportion of engineering tutorials would you estimate that you have attended ?	
Almost all/all	___
More than two-thirds	___
More than half	___
More than one quarter	___
Very few	___

Are there any particular reasons for not attending engineering tutorials ? ___

___

The following are some statements made about engineering tutorials. Please indicate if you agree or disagree with them.

	agree	disagree
I do not get as much help as I would like from them	___	___
I wish they would go through problems on the board	___	___
Tutorials in other subjects should be like engineering tutorials	___	___
The class is too big	___	___
I would like a smaller group with one member of staff	___	___
I would like specific problems set for specific times	___	___
I wish the problems could be properly marked	___	___
It takes a long time to get help in the class	___	___
I like the presence of all three lecturers	___	___
I seldom ask questions about the lectures	___	___
I feel rather inhibited about asking for help	___	___
There should be more time for tutorials	___	___
The problems on the sheets are too tough	___	___
I wish there was more pressure on me to work	___	___

Laboratories

Thinking about the laboratory experiments you have completed, please write down those that you found particularly interesting or uninteresting. Please give the name of the experiment and the department concerned.

Interesting	Uninteresting
1 ________	1 ________
2 ________	2 ________
3 ________	3 ________

The laboratories aimed to cover a very wide range of topics and to introduce many of the practical aspects of engineering. Have you any suggestions on activities that you would have found worthwhile during the laboratory time that you did do or didn't have enough time to do ?

____

____

____

Do you have any comments on the form and organisation of laboratory reports ?

____

____

General

Do you possess your own copy of either volume of 'How Things Work' YES NO

How many times have you read parts of 'How Things Work'?

Very often ____
Sometimes ____
Very occasionally ____
Not at all ____

What other textbooks have you referred to in connection with the engineering course ? (Do not include books you used for Highers) ________

____

____

Has the course encouraged you to read any other books ? Please specify ________

____

Have you ever been to see a member of staff in his
(other than your counsellor)

Do you feel that there is sufficient contact between

As a result of the course, I have become more committed to becoming a professional engineer

Please add your own comments about the engineerin

Aims

Lectures

Tutorials

Laboratories

Other Aspects of the Course

riments you have completed, please write down three
ting or uninteresting. Please give the name of the
cerned.

Uninteresting

1 ______________________

2 ______________________

3 ______________________

very wide range of topics and to introduce many of the
Have you any suggestions on activities that you would
laboratory time that you did do or didn't have enough

form and organisation of laboratory reports ?

ither volume of 'How Things Work' YES NO

ts of 'How Things Work'?
Very often ___
Sometimes ___
Very occasionally ___
Not at all ___

rred to ______________________
course ?
(Highers) ______________________

read any ______________________

Have you ever been to see a member of staff in his office ? YES NO
(other than your counsellor)

Do you feel that there is sufficient contact between students and staff ? YES NO

As a result of the course, I have become more
committed to becoming a professional engineer AGREE NOT SURE DISAGREE

Please add your own comments about the engineering course

Aims

Lectures

Tutorials

Laboratories

Other Aspects of the Course

Thank you for your assistance

SKILLS TUTORIALS : A CASE STUDY

Introduction

One of the novel features of the new first year engineering course is the skills tutorials. These have been incorporated into the course on an experimental basis and their development is being supported by one of the Nuffield Foundation small grants for innovation in university teaching. The reasons underlying the adoption and implementation of this teaching method at Strathclyde are complex, but this case study will attempt to briefly summarise the main features of the theory and practice of skills tutorials and will examine some of the reactions of students and staff to the small scale trial of the method which has been conducted in the 1975-76 academic year.

What are skills tutorials ?

Skills tutorials are designed to help students acquire some of the conceptual skills that are required in the practice of engineering. Their detailed format depends on the tutor who is taking the skills tutorial, but the main features can be listed as follows :

Introduction

The tutor presents a problem to a group of twelve to sixteen students. He explains the relevance of the problem to engineering practice and how it fits in to some other ideas that the students will already have met. The problem is normally quite unlike the normal type of question that a student would see on a problems sheet or in an examination. It is usually open-ended, it is based on very simple scientific principles, it can require judgement and estimation abilities on the part of the students, not all the necessary information is always given, the students have to decide how to present their answer, and the answer is not necessarily single valued and clearly defined at the start. In short, the problems are much closer to real engineering problems.

No more than five minutes is normally spent on the introduction.

The students are divided into groups of four or five, often arbitrarily, and each group is presented with either the same or similar problems.

The sub-groups

Three or four groups of students work on their own without the presence of the tutor for about thirty minutes. Their instructions are to decide collectively how they will tackle the problem and be ready for anyone of the group to present their solution to the class at the end of their time. The tutor stands back from the discussions and does not interfere in the group activity.

Presentation

The students gather in the total group and a spokesman from each sub-group is invited to describe his group's approach to the others. A blackboard or overhead projector is available to assist with this. Once the solution is presented then students from other groups are encouraged to ask questions and make comments about the particular solution. Each group spokesman presents his group's findings in turn and discussion on the comparative merits of the (usually) different approaches ensues. The tutor mostly acts to draw out the students and is careful not to channel discussion along his preconceived lines.

Conclusions

On some occasions it is felt appropriate that the tutor makes some statement about how the students have tackled the problem, but not in the form of 'giving them the answer'. If the questions are carefully chosen and the discussion has been well conducted then it should not be necessary or desirable for the tutor to state what he thinks they should have done. Invariably different groups take different paths to similar answers and it is often not possible even to judge what was the best approach.

What are the aims of the skills tutorials ?

The scheme for the tutorials was originally proposed with the aim that students would be able to develop some of the conceptual 'skills' that are central to any form of engineering. The particular areas that were to be developed were :

- translation from written formulations into diagramatic and graphical forms. The use of diagrams and words.
- making estimations of orders of magnitude, uncertainty and tolerance in measurement.
- analysis of the stability of simple structures, wheels and cones.
- judgements of alternative methods and procedures in a simple process. Formulating problems.

An important aim of the whole process of the skills tutorials was that students would be able to gain confidence in communication and develop their abilities at explaining themselves in front of others. They would be in the position of talking about engineering problems in a small group and then having to defend their conclusions in debate with others.

Origins of skills tutorials

The idea for skill sessions was proposed by a group of physicists at the University of Birmingham arising from their experience of small group teaching with English first year physics students.[1] This work was informally discussed at Strathclyde by Dr. Boud who had been associated with the Nuffield Foundation funded Higher Education Learning Project (Physics) which had been active in, amongst other things, developing small group teaching methods in a variety of university science courses.

The ideas were taken up by staff both in the Department of Pure and Applied Chemistry and the Mechanical Engineering Group for adaption and use in the second year chemistry and first year engineering courses respectively.

In mechanical engineering, Mr. T. G. F. Gray persuaded some of his colleagues to collaborate with him on the development of what were called skills tutorials in the first year course and he applied for, and was granted, a Nuffield Foundation small grant for the improvement of university teaching. This grant provided money to sponsor meetings and to cover travelling costs involved in learning more about the use of the methods. The subsequent discussion will refer to the mechanical engineering experience except where otherwise indicated.

A residential meeting for interested staff was held at Ross Priory in April, 1975. One of the originators of the approach, Professor P. J. Black from Birmingham, was specially invited to talk about his experiences with skill sessions and the first steps were made to plan for the introduction of sessions into the new first year engineering course. This was attended by nine engineering staff from the three departments that would be providing the lecture component of the course.

Some specific suggestions for skills tutorial type problems were made at that meeting and those present showed cautious enthusiasm for the aims of the exercise.

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[1] P.J.Black, J.A.R.Griffith and W.B.Powell, "Skill Sessions", Physics Education 9 (1), January 1974, pp 16-23

Between April and September the detailed administrative arrangements for the first year course were planned. Provision for lectures, tutorials and laboratory classes were of highest priority but, with difficulty, room in the timetable was eventually found for skills tutorials. They would take place between 2.30 and 3.30 on Monday afternoons between the regular problems tutorial and the laboratory class in the Mechanics of Materials. The total number of skills tutorials would be twenty and each student would attend three spread throughout the year. These three classes would be composed of two-thirds different students on each occasion and would in all likelihood be conducted by three different tutors. The timetable would not announce a skills tutorial as such but students would find one when they arrived in the mechanics of materials laboratory.

A second meeting at Ross Priory between the staff who would contribute to the skills tutorials was held for one day in the week before the beginning of the Autumn term to finalise arrangements and agree on the details of problems to be used in the first term.

Skills tutorials in practice

During the year nine different members of staff from three departments conducted these tutorials. Six only took part in one, but three of them conducted seven, four and three respectively. As would be expected, the tutors possessed different teaching styles and they had a wide range of experience of university teaching. Small group teaching is uncommon in the Mechanical Engineering Group and for most members of staff who took part the format of skills tutorials was different from their normal teaching responsibilities.

At first the sessions were characterised by a degree of uncertainty. Staff were unfamiliar with the method and were modifying both their own approach and the method to suit the situations they found. Students were very passive; they were new to the university, somewhat ill at ease and diffident about expressing themselves openly and clearly. Both staff and students expressed some discomfort about the method.

As staff gained more experience with the method and as they picked up ideas from each other the tutorials tended to become less tense. The students grew in confidence throughout the year, but the effect of the skills tutorials on this cannot be determined. Their attitudes changed; they became more interested and took part more fully in the exercise. Also, as staff became used to the situation the problems became more applied and more obviously related to engineering.

Tutor style

Various tutor styles were apparent. The two most common styles can be characterised as the authoritative and the facilitative, although these are not rigid categories. The authoritative tutor tended to ask many more specific questions demanding specific answers. He took a greater role in the discussion and all points of view tended to be directed through him. Little cross discussion amongst students could be seen in the final discussion. Some authoritative tutors would visit the sub-groups to inject ideas, suggest specific lines of thought and check that good progress, in their terms, was being made. In the closing session, the authoritative tutor would often present his solution to the problem, taking the analysis much further than had been reached in the discussion. The facilitative tutor took a much less dominant role. He tended to ask questions that sought to help students continue their train of thought and to clarify for themselves what they were seeking to express. He encouraged cross questioning amongst students and was willing to pursue paths that he had not thought of himself. He visited the sub-groups somewhat less and,when there,spent much time listening to the students and encouraging new ideas. In the final part of the session he would sometimes summarise points of view, but would resist any elaborate analysis or propagating too strongly his view of the situation. A third style, rather less common, could be termed the laissez-faire style. The laissez-faire tutor tended to leave a path of uncertainty in his wake. The task he suggested was sometimes unclear. He would move from stage to stage of the discussion, quite arbitrarily, sometimes breaking a train of thought or leaving a question in the air. He would often let a discussion continue unchecked so that insufficient time was available for other points. He was very reticent about intervening but when he did he was likely to do so rather sharply. The final part of the session would sometimes close abruptly and inconclusively.

These three styles have been drawn starkly to emphasise their differences. It was rare for any one session to be conducted exclusively in one mode. However, they do seem to have very different effects on the students. Not unexpectedly, the laissez-faire style was not seen as very productive, students' response was expressed in such phrases as, 'that was a waste of time', 'I couldn't see where we were going' and various non-verbal signs of relief at leaving the room. It was much more difficult to distinguish between the effects of the other two styles from the responses of the students. The authoritative style is the one with which they are very familiar and it is the norm in nearly all the other teaching they experience at the university. It is in keeping with their expectations and is something that they feel unable to judge objectively. The phrases, 'well, he's just like that' or, 'it's what you expect from a lecturer' would be typical. In many ways, the facilitative style is the most difficult to judge of all. It aims to be non-obtrusive and when it works well the students feel that they have had a useful and productive time without being conscious of the tutor's role in it.

It is, perhaps, not very productive to dwell at too great a length on these styles.

It is not as if a tutor could change just by giving thought to the matter. What is clear is that no matter what the style, certain points about the method are important for the tutor if he is to accomplish his task within the set time. These can be summarised in terms of the students' view :

- The students should know at all times exactly what their task is and how long they have to do it.
- The students should know what is expected of them and how they will present their findings.
- The students should be given sufficient time to express themselves without being interrupted.

Organisation

Due to the severe timetabling constraints the students got much less practice with this type of situation than the staff. The maximum number they could have experienced was three, although in error four students did attend four sessions without even being aware that anything was wrong. The students were never in the same group, or even with students on the same course of study. It was notable that attendance was very high, higher indeed than the regular tutorial which preceeded it, and that attendance did not fall during the year. The problem of lack of continuity, though, was one that was expressed by many staff, perhaps it was not so large in the minds of the students as they were used to a fragmented and complex laboratory timetable and regarded continuity as something that was not part of the system. Usually there was a gap of two months between skills tutorials and when they did attend them again the students would often find a new tutor, a new kind of problem, a new set of fellow students (except for his immediate lab group) and a new room. Staff could not assume that students were familiar with the procedure, with working with each other or certainly not expressing themselves publicly. Each skills tutorial had to start from scratch.

The environment

As the skills tutorial was timetabled as part of the laboratory period, a laboratory was allocated for the purpose. At the start of the year the sessions were conducted in the centre of a fairly large laboratory. The students gathered around a moveable blackboard for the discussion and sat cramped together on stools wedged between benches. The laboratory was a thoroughfare to others and interruptions from staff and technicians talking in other parts of the laboratory were not rare.

After the first term the tutorial was moved to a side laboratory which it occupied alone. There were no interruptions and an overhead projector was usually available. The students were still somewhat cramped though and when the laboratory started to get progressively filled with large research apparatus the tutorial had to be moved elsewhere.

Its final resting place was far more conducive to its aims. It was a conference room with a collection of tables which the students could sit around facing each other. The overhead projector was available, there were comfortable seats and each person could be heard.

The students' response

In order to assess the students' reactions to the tutorials a brief questionnaire was prepared. It consisted of thirty statements that had been heard from staff and students throughout the year. Students were asked to agree or disagree with each and were given an opportunity to make a neutral response. In addition three open questions were asked concerning comments on the questionnaire, suggestions for improvement of the skills tutorials and other comments about them or other aspects of the course.

Fifty three students, all of whom had experienced three skills tutorials, completed the questionnaire in the last five to ten minutes of the final tutorials of the year.

To summarise the most clearly expressed views, (30 out of 53 students) students would support the following statements about skills tutorials in order of popularity .*

1. It is easier to have a discussion when the other students present their ideas clearly (48 agree, 3 not sure, 2 disagree)
2. It's good working in a small group (47, 2, 3)
3. They were not a complete waste of time (44, 1, 7)
4. They have not encouraged me to look something up in a book (43, 3, 8)
5. They are more related to 'real' engineering than the class tutorial questions (40, 6, 9)
6. I can see the point of the skills tutorials (39, 3, 11)
7. Skills tutorials ought not to be abandoned (38, 5, 8)
8. The problems discussed help one to learn how to think as an engineer (37, 7, 9)
9. I found them interesting (37, 5, 11)
10. I wish we could have been told the accepted answers (37, 3, 11)
11. They are not boring (36, 3, 12)
12. We learn more about how to tackle problems because a group of students is left to work on their own for a while (35, 5, 13)

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* some of these statements have been transposed for sake of clarity

13. The examples were not unrealistic (34, 8, 10)

14. I didn't realise that there would be so many points of view on some of the questions (34, 7, 12)

15. They had relevance to the rest of the course (34, 5, 12)

16. They help us communicate about the subject (33, 6, 12)

17. The tutor does give enough guidance during the skills tutorials (33, 4, 15)

18. You don't get a chance to develop skills when the skills tutorials are so spread out during the year (32, 6, 14)

19. They are not going to help us with the exams (31, 8, 14)

20. We need more tutorials, but of a different type, for the engineering lecture course (31, 7, 15)

For the following statements there was much less agreement amongst students although a clear majority were in favour :

21. Time would not have been better spent on difficulties arising from lectures (29, 6, 17)

22. I do think they have helped me develop 'skills' (29, 4, 18)

23. The problems should not be related to actual examination questions (29, 3, 19)

24. I can talk more easily in the small groups when the tutor isn't present (29, 5, 20)

25. They help me to get to know other students (28, 8, 16)

The following were much more evenly split :

26. I like problems with no definite answer (27, 2, 23)

27. They should not have been run differently (25, 11, 16)

28. They would be more helpful later in the course (25, 8, 19)

29. Staff should not ask more questions in the final discussion (22, 9, 21)

30. The final question : 'The room was unsuitable and uncomfortable' was answered differently by groups who occupied the different rooms. Those using the corner of a laboratory agreed with this statement (17, 2, 6), those using the conference room disagreed (22, 0, 4).

Some questionnaires were administered to groups of students in February who had only experienced two skills tutorials. Their attitudes differed from the above on some issues. At that time they did not think the tutorials had helped them develop any skills and they did not find them interesting. Some of this group were subsequently re-assessed after three tutorials and their views had changed a little in the direction of being more favourably disposed towards them.

The responses of the group of four students who, for unknown reasons, appeared to have taken part in four skills tutorials were in broad agreement with those who had taken the normal number.

Issues raised by students

The open ended part of the questionnaire gave an opportunity for students to give their views at greater length and several issues were raised that were not fully covered by the questions asked in the first part. 76% of the students made some response.

Students varied in the extent to which they appreciated the aims of the exercise. Some restated what they saw to be their purpose, for example, "I think 'skills tutorial type work will be useful since engineers in industry will be asked to solve problems, and will not be allowed to do this in isolation, but in groups pooling their ideas at least some of the time. The practice in communication is therefore helpful." Some others found difficulty in knowing why they were doing it then and were confused by the use of the word 'skill' which they identified with some practical activity.

As can be seen from the ratings, many students were worried about not knowing what were the "correct" or "accepted" answers to the problems. They associated the skills tutorial problems with the close-ended questions with which they were very familiar and found it frustrating that they did not get such straightforward answers or that such answers did not exist, "I think that the tutor should go through what is considered to be the correct procedure and conclusions so that we know whether or not we are adopting the correct approach." Many found difficulty in appreciating that there might not be one correct approach to a problem. A minority of students seemed pleased that the problems were not so 'artificial' as those on the problem sheets and welcomed the greater sense of relevance which they perceived.

Relevance was another factor over which students disagreed. Many remarks were made that the skills problems should be more realistic and related to the practice of engineering, "more often with actual examples of problems discussed by industrial engineers", "the examples are too basic and simplified", "maybe if they were related to actual problems that have occurred in the past, then we could compare our solutions with the original". But, as mentioned above, students contrasted the skills tutorials with other parts of the course which they saw to be even less related to what they thought engineering would be.

In addition to this problem of intrinsic relevance, the frequent issue of extrinsic relevance appeared : "they are not going to help us with the exams". One student pointed out that he would disagree with this statement if he "knew that there was to be a discussion question in the exam". This was compounded by the anxiety of some students that the regular tutorials were not as much help as they would have wanted in preparation for the examinations. The statement, "we need more tutorials, but of a different type, for the Engineering lecture course" seemed to be supported for this reason but a number of students wrote in that they thought it difficult to judge the worth of the skills tutorials as they had had so few of them. Some were very enthusiastic and suggested that "we should have them every week".

The uncertainty of some of the staff and their degree of commitment to the exercise seems to have been transmitted to the students, as one pointedly remarked, "the lecturers apparently have little faith in the validity of the skills tutorials'.

The response of staff

One of the components of this evaluation of the skills tutorials was the direct observation of the tutorials themselves. In all, fifteen out of twenty were attended and field notes were made both of the sessions and of the response of the staff who were leading them. It was observed that almost all of the staff took their task very seriously and observed at least one of their colleagues conducting a tutorial before they tried themselves. This act of observing colleagues did have the effect of sharing some of the small items of technique and procedure that were particularly helpful. For example, it was commonly found that the maximum size of the sub-groups was five students and even then, on occasions, they split into two and three, or with an isolated student. Groups of, at most, four were preferred but it was not clear whether or not larger groups would have worked in a more comfortable environment: it was difficult in the laboratory setting for groups of more than four to congregate easily. This factor meant that the regular laboratory groups of six or sometimes more students had to be split, thus contributing to the general fragmentation of the exercise in the course; it was thought preferable to do that rather than lose students who might not contribute in a larger sub-group.

Towards the end of the skills tutorials all staff who had taken part were circulated with a list of headings or issues concerning skills tutorials and asked to comment under each. Six out of nine had been returned at the time of writing. The three that were not returned would have been from staff who had taken only one skills tutorial and some felt that it was difficult to judge with so little experience. The following discussion is based on the issues listed in this brief questionnaire and draws on both the responses of the staff who returned them and on the comments of others in informal discussions or interviews.

Aims

It had become clear that there was some divergence between the aims that were originally proposed for the skills tutorials and what in practice they aimed to do. The acquisition of conceptual skills gained less prominence as it was realised that little could be done in such a short period of time. Some of the aims in practice which were cited by staff were :

> "to get students to think about skills other than those
> which are involved in 'numerical' tutorials"

"to let them see that there may be more than one idea about the problem in hand"

"to give them the experience of working with others in a small group"

"to give them experience of communicating with others about engineering"

"to face some real engineering situations for the first time"

"to help students look more objectively at problems"

"to cultivate intensive thought by encouraging students to look at problems from a variety of points of view before plunging into detailed analysis"

Strengths

The staff saw the main strengths in terms of getting the students to work with each other in group discussion; "the experience of discussing and putting forward views in public", "confidence in tackling problems" and getting to know each other and getting to know staff. They also thought it worthwhile that students had seen and had experience of problems with many more factors, sometimes non-technical factors which they do not normally consider and "realisation that actual problems do not have an explicit answer".

Weaknesses

They were less successful, as has been mentioned, in terms of one of the original aims, "they do little to develop the conceptual skills which are the excuse for the exercises" and in their ability to get all the students involved, comments were made that "students need not participate if they feel so inclined", "not everyone is drawn in" and "only the clever and attentive students benefited. These comments should be seen relative to the skills tutorials and not the rest of the course as the degree of involvement of students is far higher[1] than the regular tutorials which one third of the students fail to attend. The students did participate more and more students participated in the discussions as the year progressed, but by the end it was still possible for some students get fully involved. However, as the other weakness was seen to be the fact there were so few it would seem premature to judge that students would not get more involved if the skills tutorials became more regular, with greater continuity.

The formulation of some of the problems was identified as a weakness by some, "the range of problems could be improved", "the standard of the skills tutorial problems could be improved. I suggest more emphasis should be placed on problems where there are alternatives." One member of staff thought that there was a weakness in the preparation of students and he remarked on, "a surprising built-in preconception.... ..even at first year level. It was revealing that we don't do all the conditioning

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[1] The effect on attendance at skills tutorials of the compulsory laboratory class which follows cannot be determined.

(of the students) as we are often told we do."

Place in the course

The staff concerned were very dissatisfied with the present arrangements for timetabling. Many of them felt that many compromises had to be made to get them incorporated into the course at all and that they could not continue on their present basis. Some would like them to be separate from the laboratory, "and seen to be separate", and to be regular, "to be of value, skills tutorials should occur once per week", one person commenting, "if this cannot be achieved they should be abandoned", and another suggesting that,"they need to do more exercises in a more concentrated period, say, at the beginning of the session and the end of the session", and another thought that, "more time should be spent on these problems". One person did point out that being associated with the laboratory time might be an advantage as it "seems to ensure attendance and participation".

Ideas for improvement

Many of these have been touched on in the preceding account. Some of the suggestions can be listed as follows :

1. Increase the number of skills tutorials.
2. Make them more regular
3. Ensure greater continuity
4. Reduce numbers to twelve (3 groups of 4 or even less)
5. Find suitable rooms, not a lab or lecture theatre
6. De-bug the exercises in the light of experience, and build up a range of exercises
7. Use and develop the technique of using overhead projection
8. Forge better links with students' other work (standard tutorials)
9. Use elaborate problems towards the end

To this list, for the sake of completeness, the students' ideas can be added :

10. Develop exercises with obvious relevance to real problems
11. The objectives of the skills tutorials should be reflected in the examinations, if they are really important

Different staff have placed different emphases on the aims that they are hoping to develop in skills tutorials and the kinds of exercises that they would like to develop.

The original procedure and aims of skills tutorials have expanded through practice and experience and it is now important to clarify the objectives and methods for future skills tutorials. There seems no reason to restrict them too narrowly to a given formula, but if changes in the format are to be made then there must be very clear reasons and the new procedures should be carefully monitored. Perhaps some consideration is needed before any substantial changes,other than those listed, are made.

Comparisons between the experiences of skills tutorials/sessions in Physics, Chemistry and Mechanical Engineering

The use of skills tutorials has been monitored by the staff involved in physics at Birmingham and in chemistry and engineering at Strathclyde and certain common features emerge in the reactions of students.

Students are very critical of problems that they see to be 'unreal' or 'irrelevant' This applies both to the extent to which the problems mirror problems in the 'real world' and in their relevance to the rest of their course. Unless they can see some application of the problems they are given to the practice of their subject they will be dissatisfied and not enter into the situation wholeheartedly. Also, if they see that the skills tutorial component of the course is not recognised by staff as important, and importance they see manifest in the examination questions, then the students see little reason to think them important and invest their energy in them. If anything, Strathclyde students in both subjects were less tolerant of 'artificial' problems than Birmingham physicists, but all groups wanted the skills tutorial component to fit in and relate closely to the rest of their course.

The other comparative observations that might be made about students' reactions is that students seem to be more favourable with the more experience they get of the method; this was very clear amongst the Strathclyde engineers. The chemists only had two sessions and their reactions were comparable to the engineers when they had only experienced two and both these groups were more critical of the ways in which the sessions were conducted than the physicists who had had them regularly throughout the year and whose staff had more experience with the teaching method.

What has been learned from skills tutorials ?

The exercise of developing this innovation in engineering teaching appears to me to have had some considerable effect, independent of the success or otherwise of the scheme. As some of the staff have expressed, "it was the first time that there has been real co-operation between the departments on the course". Nine staff had worked together out of interest and a concern to see the first year course prosper, they were from three different departments and they had freely chosen to devote their energies to this development. Not unexpectedly in a completely new venture, their aspirations reached somewhat further than their achievements, but it is clear that the achievements have been sizeable within the very tight constraints of resources and scheduling. It is my opinion that the climate towards educational development in the mechanical engineering course has been changed by the exercise and that future co-operation will be much more easily achieved.

With respect to the skills tutorials themselves, the first year's experience has given a more realistic view of what can and cannot be achieved in such sessions and on such a scale. A great deal of experience has been gained,by all those that took part,about small group teaching in engineering and the problems and potentialities of it, and awareness has developed in staff of some of the abilities that they could be developing further in students. The next stage of the experiment would be to use this experience to develop small group tutorials in the first year course on a more stable and systematic basis and to see the effects that would obtain if students were to have a more complete exposure to this approach.

SKILLS TUTORIALS QUESTIONNAIRE

Skills tutorial is the name of the session which occurs from 2.30 to 3.30 on afternoons when you have a Mechanics of Materials laboratory class.

The aim of this questionnaire is to give you an opportunity to give your views on these sessions. The staff involved have been developing these skills tutorials this year and they would appreciate your comments about them – what you think of the skills tutorials and any ideas you have for their improvement.

Dr. Dave Boud
Leverhulme Project

Below is a list of statements that have been made about skills tutorials. Please indicate whether you agree or disagree with each by underlining the appropriate word. If you are not sure, circle the question mark, but try to use this as little as possible. If you wish to add comments to any question, please do so at the end.

How many skills tutorials have you taken part in ? 0 1 2 3 4

I wish we could have been told the accepted answers	agree	?	disagree
They have encouraged me to look something up in a book	agree	?	disagree
They are more related to 'real' engineering than the class tutorial questions	agree	?	disagree
I don't think they help me develop any 'skills'	agree	?	disagree
They help us communicate about the subject	agree	?	disagree
The staff should ask more questions in the final discussion	agree	?	disagree
The examples were unrealistic	agree	?	disagree
I found them interesting	agree	?	disagree
You don't get a chance to develop skills when the skills tutorials are so spread out during the year	agree	?	disagree
They are not going to help us with the exams	agree	?	disagree
They are boring	agree	?	disagree
They had no relevance to the rest of the course	agree	?	disagree
They would be more helpful later in the course	agree	?	disagree
I don't like problems with no definite answer	agree	?	disagree
The problems should be related to actual examination questions	agree	?	disagree
We need more tutorials, but of a different type, for the Engineering lecture course	agree	?	disagree
They were a complete waste of time	agree	?	disagree
They should have been run differently	agree	?	disagree
Time would have been better spent on difficulties arising from lectures	agree	?	disagree
It's good working in a small group	agree	?	disagree
The room was unsuitable and uncomfortable	agree	?	disagree
I didn't realise that there would be so many points of view on some of the questions	agree	?	disagree
I can talk more easily in the smaller groups when the tutor isn't present	agree	?	disagree
I can't see the point of the skills tutorials	agree	?	disagree
It is easier to have a discussion when the other students present their ideas clearly	agree	?	disagree
They help me to get to know other students	agree	?	disagree
The problems discussed help one to learn how to think as an engineer	agree	?	disagree
We learn more about how to tackle problems because a group of students is left to work on their own for a while	agree	?	disagree
The tutor does not give enough guidance during the skills tutorials	agree	?	disagree
Skills tutorials ought to be abandoned	agree	?	disagree

Comments on the questions above

Do you have any suggestions about how skills tutorials might be run differently ?

Any other comments about skills tutorials or the rest of the course ?

Thank you for your co-operation

PART THREE

ISSUES IN UNDERGRADUATE ENGINEERING EDUCATION

RECOMMENDATIONS AND PROPOSALS

Part III is devoted to an examination of issues that have been met during the course of the project. Some of these are concerned with mechanical engineering education in general, some with course structure and development in specific departments in the two universities, whilst others involve the nature and purposes of educational projects of the present kind. The issues therefore relate to different audiences. It will normally be clear from the context which of these audiences is being addressed. As the majority of time during the last year of the project was spent with the mechanical engineering course at Strathclyde the concerns of this group are predominant and unless otherwise indicated the observations that underlie the issues are drawn from this source.

This section will examine some of these items in rather greater depth and will draw upon some of the empirical findings that have been presented in Part II. In particular, it will make some tentative suggestions about future developments in the two universities. These are offered for further consideration by the appropriate bodies

SOME ISSUES IN UNDERGRADUATE ENGINEERING EDUCATION

The case studies of the first year engineering course, skills tutorials and the aims of mechanical engineering education which were presented in Part II only form part of the empirical work of the project. Other aspects have formed the basis of confidential reports to the departments concerned and yet other work has been undertaken for particular groups of staff on problems which they identified. Throughout the project the present research fellow has attempted to immerse himself in the activities of the departments concerned in as far as it is possible within his identified role. This has involved attending meetings : discussing courses, staff meetings, School Board meetings : conducting interviews with staff, meeting staff informally : observing classes, lectures, tutorials and laboratories : inspecting documents, syllabuses, minutes, examination papers, student statistics and employment records : conducting one-to-one and group interviews, administering questionnaires and informal meetings : and wider study of the field of engineering education.

Only part of that experience is captured in Part II of this report. Many problems and issues were met that did not fall comfortably within the scope of any of the detailed studies, but which were of obvious significance to undergraduate education as a whole. Some of these issues have already been discussed at length with staff.

This chapter aims to articulate some of them. Those which are included have not been taken at random, but have been chosen for one of two reasons. Firstly, they are issues that have already been the subject of much debate but without any agreed solution, for example, the role of industrial experience in undergraduate education. The second reason for inclusion is that they represent problems which, in my opinion, underlie current difficulties but which as yet have not been fully expressed, for example, the encouragement of the dependency of students on the staff.

Many of these ideas and inferences will be made on the basis of my judgement and they cannot all be immediately and clearly related to empirical evidence. Some of the most important educational issues of all can be informed by evidence but are essentially matters of judgement of values.

The wider issues of engineering education will be discussed first. These include a consideration of the boundaries of engineering education : where does the responsibility of the university department end and begin at the undergraduate level, and the role of professional or industrial training within the course. The second group of issues focuses on the undergraduate curriculum as it presently exists and looks at the boundaries of subjects; teaching methods in the course; assessment limitations and possibilities; the dependency of students on staff and the coverage of the curriculum. The final group of issues is concerned with course development in the two universities and problems and possibilities in this area that are manifest in the courses that have been studied but probably have wider impact within the universities. These include the notion of systematic course development; planned change and reasons for innovation and university staff training.

Boundaries of Engineering Education

The first degree is but one element in the training of a professional engineer. There are at least four components of the life-time education of an engineer : pre-training, including initial schooling and/or work experience; the undergraduate course; the postgraduate course and/or industrial training scheme; and continuing education, post-qualification. Involved in this are many bodies : schools, further education institutions, universities, industrial training establishments and companies themselves. And overseeing these activities are many other institutions : the universities, CNAA, the Engineering Industry Training Board, the Council of Engineering Institutions, individual engineering institutions and businesses. There is a clear question here. Where does the responsibility of the individual university, and,particularly,the Engineering Departments lie ?

It is agreed that at least they are responsible for the academic content of the undergraduate and postgraduate courses that they offer. But this certainly cannot be seen in isolation from the rest of the professional education of which it only forms a part. Some universities run and others have in the past run sandwich courses which were supervised by the university who insured that the industrial component was providing an adequate practical training as well as work experience. Indeed, some universities award an endorsement to their degree certificates and an additional qualification to those students who successfully complete a planned and supervised training activity on an industrial year, cf.,the Associateship of the University of Surrey Award, AUS. This does not occur either at Strathclyde or Heriot-Watt and industrial experience or training no longer forms part of the undergraduate course in mechanical engineering.

If the university is providing only the academic element of the training can it adequately plan this in isolation from the other elements of professional education for which it is not responsible ? The problem of the boundaries between the various responsible bodies is a great one and if each body only looks to its own area of activity then the education of the engineer is in danger of being incoherent and badly balanced. When such boundaries exist then worthwhile experiences which, say, link academic and practical matters will fall in the gaps and each body will regard it as maybe the other institutions' responsibility to develop it. The clearest example of this at present appears to me to exist in the role of professional training at the undergraduate level.

The role of professional training

Up until fifteen years ago, the undergraduate mechanical engineering course at Strathclyde consisted of two terms per year of study at the university for four years interspersed by six-month periods in industry. Over the last fifteen years the industrial training component has been progressively eroded due to pressures within the university, the demand to include more subjects in the course, and the difficulty of placement due to economic recession. Now a re-designed course has been approved which contains no element of industrial training. During a similar period there have been changes in the increasing undergraduate intake. The number of students entering the first year with any form of industrial (or work) experience has declined, so also has the number entering with Higher National qualifications in later years. At the same time, the number of overseas students with no experience of British industry and sometimes little practical experience of industry in their own country has risen steeply. The students of today have collectively less practical experience than those of only ten years ago.

The situation has thus developed whereby today's graduates have significantly less practical experience and contact with industry than those of the past. They have not gained this for themselves and it is not provided as part of the course. In addition, it is proving difficult for students to work in the engineering industry during summer vacations due to the current recession, and the numbers enrolled on the undergraduate course are so large that the departments would find it impossible to reliably place them all, even if they decided that it was desirable. In parallel with these changes, the provision in industry for training has modified. Until recently, most large firms had their own apprentice schools to train their own workers and students in workshop practices; now there are very few such schools and provision for pre-graduation workshop training is conducted almost entirely outside industry in colleges of further education and technical colleges.

Whilst the content of professional training is being more systematically prescribed by such bodies as the Engineering Industry Training Board and the Institutions,[1] the higher demands that are made by the EITB on training have concentrated provision in more specialised institutions and have moved training away from productive industry. Substantial improvements have been made in systematic training at the graduate level where many good graduate training schemes are provided by large companies and corporations, but the opportunities of direct involvement with industry at the undergraduate level have severely declined.

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[1] For example see, 'Training in Mechanical Engineering Practice for Chartered Engineers', the Institution of Mechanical Engineers, 3rd edition, March 1976. The latest edition of this booklet places more emphasis on business appreciation for student engineers, and strengthens the industrial training requirements.

The problem presently exists of what form should such experience or training take and who should be responsible for providing it. It is not sufficient to suggest that a specified amount of work experience should be required for students entering undergraduate engineering courses. This would just move the problem without in any way contributing to its solution.

The diversity of official institutions involved in this problem compounds it. Many engineering departments at both universities feel that their hands are tied by the CEI and, to some extent, the EITB who make demands for experience and qualifications with which the university has to comply if its degrees are to give exemption from some of the other requirements for becoming a chartered engineer. What none of these bodies can provide is the money to pay for any of the training schemes and until some financial support for students is forthcoming the university departments will feel that there is little that they can do.

The educational issues that are raised by this are central to university and professional education. Is it desirable that graduate engineers should be produced, by universities, with little or no 'practical' experience ? Does the academic part of professional education best exist in isolation from the practical ? Is it educationally desirable for professional education to be split into an academic component and a practical component existing entirely separate from each other ?[1] If the answer to these questions is no, then a major change is needed in the structure and finance of engineering education. Responsibility for initiating such a change lies with the university as much as with anyone else.

Issues in the Undergraduate Curriculum

Although reference will be made to the two universities to give specific examples, all of the issues to be mentioned are of much wider significance. It would be rare to find any institution of higher education that has dealt to its own satisfaction with more than a few of the items to be discussed.

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[1] Smithers draws attention to the findings that many of the sandwich courses in British Universities that were ostensibly designed to integrate the academic and practical components, fail to do this in the eyes of the students. He also recommends a rethinking of the sandwich scheme as it stands. A. G. Smithers, 'Sandwich Courses : an integrated education ?', NFER, 1976.

Boundaries of subjects

Most single subject degree courses like Mechanical or Civil Engineering are the responsibility of a single department within a university. In those departments are to be found specialist and generalist staff who contribute to the various parts of the courses. In small departments there are usually only a few staff who specialise in one part of the subject area and there is usually close contact amongst these staff with possibly collaborative research between different areas. This is the case in Mechanical Engineering at Heriot-Watt. In larger departments there are greater numbers of specialist staff and they form formal or informal groupings around research interests. And in some cases they grow so large that they split into sub-departments, or even departments in their own right. The latter is the case in Mechanical Engineering at Strathclyde. There are six independent departments or units which form an informal grouping called the Mechanical Engineering Group :

Department of Engineering Design and Drawing
Department of Dynamics and Control
Department of Mechanics of Materials
Department of Thermodynamics and Mechanics of Fluids
Department of Production Management and Manufacturing Technology
Bio-engineering Unit

In such a setting as this there is a not unnatural tendency for each department to feel that certain sections of the curriculum fall exclusively within its remit. If the curriculum is of the predominantly subject-centred kind that is to be found in mechanical engineering, then the existence of independent specialist departments does lead to a compartmentalisation of any shared course, unless special steps are taken to the contrary. Each department is proud of the subject that it expounds and wishes to protect those parts of the curriculum in which its staff feel they have particular knowledge.

In this situation the course tends to be moulded in the image of the existing subject areas represented by departments and, because there is no independent method of assessing priorities within the course, it is common for the curriculum to be developed to maintain parity between the departments involved so, for example, the lecture time on the new first year course is equally divided between three of the departments and the balance between contributions from different departments has to be carefully maintained.

Little cross fertilisation can occur without effort. The first year course is a good example of how this is just beginning to occur. Although more discussion between different departments had taken place with regard to this course than any other it did not prove possible, as described in Part II, for the lecturers to co-ordinate their teaching more than agreeing on who should teach which topics and, even within that, some overlap occurred of which other teachers of the first year were unaware. Despite exchange of lecture notes and an 'integrated' course during the first four weeks,the course that emerged appears to be subject-centred in the departments that contributed to the course.

This is not necessarily inappropriate. Whether it was or not would depend on the aims of the course and particularly the aims of the first year course. Care had been taken to express the aim that the course would be a unified course in engineering but the structure made this almost impossible to achieve in practice. The structure and organisation does represent a significant change over the arrangements for other years of the course where there seems to be relatively little co-ordination. Each course has its own class 'registrar', a member of academic staff who is responsible for the timetabling, examination paper organisation and general administration of that course; he does not take any academic role with respect to that particular course unless he is otherwise lecturing to the class, which is usual. The new first year course had one class registrar , that is, the course was treated as one course even though it was being contributed to by staff from three departments. However, in later years when each department runs its own courses, each with its own class registrar , each year finds itself with several registrars . Although the three or four class registrars for each year co-ordinate administratively, there is no educational co-ordination, and no-one has special responsibility to see that a coherent course is produced from the individual elements. The responsibility for this lies collectively with the respective heads of departments.

The internal boundaries of the Mechanical Engineering Group only reflect the boundaries that normally exist between departments teaching different disciplines. It is not surprising that separate disciplines are solely responsible for their own courses. However, in the MEG the staff are mostly all mechanical engineers or working in mechanical engineering. There is a clear parallel between the problems of co-ordination of the mechanical engineering course and those of courses that cross the normal discipline boundaries. It is likely that similar approaches to the problems might by useful.

Teaching methods

Much time and effort is spent at present on discussing and preparing the content of the undergraduate curriculum. Rather, the teaching methods are usually left to the individual lecturer to work out in his own way, and it is regarded as the norm that any course, other than practical subjects, should consist of x hours of lectures, supported by approximately $^{x}/4$ hours of problem-solving type tutorials.

The staff have most experience in lecturing, they mostly feel comfortable operating in this mode. They do not appear to be sufficiently familiar with other methods[1] to use them in their own courses, or to judge whether they are desirable; they have not experienced them as students and would have to gain the experience specially if they thought it worthwhile.

Currently, the courses give a powerful unstated message to students in the ways in which they are presented. Courses are given in a similar manner, namely by lectures, where information is provided and discussed and which the students record. They then study these lecture notes in order to answer questions which are provided on problem sheets. This is the normal pattern for most of the four years of the course. The message is that engineering can be thought of as a body of concepts, information and procedures which can be transmitted from the experienced engineer to the aspiring engineer. The student has to study and memorise this information in order to solve problems which are provided and to pass the examination at the end of the year. It is well recognised by staff and by students that these activities bear little relationship to the activities of the professional engineer and the methods by which he will learn when he gets outside the institution.

If these observations are taken in conjunction with the trend for students to have much less practical experience in industry in recent years, another issue becomes clear. Students now probably have less motivation to study the more analytical and theoretical aspects of engineering than before. They have less familiarity with the concrete level of engineering against which they can balance the more abstract aspects which they find in the university courses.

University engineering courses are becoming more orientated towards engineering science, not solely through the change in content of the curriculum, but also as a result of the change in the educational environment outwith the university that is experienced, or not experienced, by students. If students have less knowledge of, and contact with, the applications of the engineering that they learn in their courses they will find it more difficult to perceive the relevance of those courses and it will tend to become more difficult to maintain their motivation.

It is well accepted that it is more difficult to learn in a context where the relevance of what is being learned is not clear; similarly the importance of learning by experience rather than vicariously is well known. This does not mean that present courses should necessarily change, but that engineering education is likely to be greatly facilitated by practical activity in its widest sense, both in the course and elsewhere. Activity of this type could include laboratory experience, simulations, case-study activities, seminar exercises, project work. That is, all forms of teaching method where the students are involved in more than simple problem solving.

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[1] See for example, D. Bligh, 'What's the Use of Lectures?', Penguin, 1972,
D. Bligh et al, 'Teaching Students', Exeter Teaching Services, 1975,
and see in particular the 'Academic Related Case Studies' being developed by Prof. J. Black and his colleagues in the Leverhulme Project, School of Engineering, University of Bath.

There is also a tendency for university courses to include more and more 'advanced' subject matter, demanding greater degrees of sophistication on the part of students. On this higher level subject matter students are asked simpler and simpler questions as they would otherwise neither be able to answer more complex questions, nor would they fit in with the constraints of the examination system as presently constituted. The idea of asking 'advanced' questions on relatively simple subject matter remains largely unexplored, for whilst this is regarded as of great educational benefit, many staff feel that it is not of sufficient status or agreed worth to teach simple subjects at greater depths of understanding and, indeed, if they do try they can be seduced into raising the level of sophistication.

It could be argued that it is much more important that students develop basic skills very thoroughly so they might have the basis themselves to tackle more advanced subjects. Attempts have been made elsewhere to do this and some non-engineering departments at Strathclyde have compulsory finals papers consisting of questions based on subjects studied in early years of the course but not tied to a particular course. Unfortunately, this is seldom more than a token as the course is rarely designed to encourage these skills. Some attempts to deal with this problem have been made in physics in the skill session and tutorkit ideas of the Nuffield Higher Education Learning Project[1] and the skills tutorial in the first year engineering course is an example of this. Examples of questions and ideas in physics that can be used in this kind of approach can be found in Walker's entertaining book.[2]

Assessment, limitations and possibilities

A similar argument can be applied to assessment. The main form of assessment at present in most engineering courses is the three hour examination. The characteristic of many of the numerical questions that are to be found is that they normally involve problem solution, rather than problem recognition; they provide just sufficient information for solution, no excess or insufficiency; and they have single valued solutions; so that no selection is required from the student.

One of the important skills that will be required of a student when he leaves the institution are that he will firstly be able to recognise problems when they occur, that he will be able to translate a real-life problem into one that is amenable to the kinds of analysis that are available, he will be able to select appropriate methods of analysis; he will be able to perform the analysis and he will be able to check his own solution when he has produced it. At present, great emphasis is placed in examinations on the penultimate of these skills, whilst some others are given less attention and others are neglected. It is only in the final year project that many of the other skills in the problem solving sequence will be developed and tested.[1] It can reasonably be argued that real problems are too complicated or sophisticated to be tackled by students but it may well be that some of the criticism of the universities' preparation of graduates by industry is to do not just with the lack of practical experience of students, but their inability to even start on a problem that is wrapped in the complexities of reality.

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[1] Higher Education Learning Project, 'Small Group Teaching in Undergraduate Science', forthcoming, Heineman Educational, 1976.

[2] Jearl Walker, 'The Flying Circus of Physics', J. Wiley, 1975.

Some concern has recently been expressed by the Confederation of British Industry on this and other matters concerning the preparation of the graduate engineer.[2] A recent survey amongst employers conducted by the CBI warns that an increasing number of recruits display poor personal motivation, little professional commitment, lack of flexibility, breadth of vision and creativity in problem solving. They also say that such graduates need close personal supervision and are deficient in inter-personal and communicative skills.

Dependency of students on staff

Any teaching situation is likely to be one of dependence of the person who is being taught and who possesses little knowledge on the teacher who, presumably, possesses more knowledge and experience. This is not surprising. However, one of the main aims of university education is generally recognised to be the encouragement of the student's independence of thought and action so that by the time the student graduates he is not dependent on his teachers for his learning, but has the skills and capacity to learn on his own.[3]

There are many signs that at present the structure and organisation of the undergraduate courses act to some extent to encourage students to become dependent on the staff. This is certainly not intended but is inherent in the style of the course. As mentioned previously, most courses are based on lectures, which form the predominant teaching medium. The main learning activities for students are the taking and study of lecture notes and the working of set problems.

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[1] An attempt to develop some of these skills at Strathclyde is made in the first year 'skills tutorials', see Case Study in Part II.

[2] 'Qualified Scientists and Engineers - Industry's Requirements from the Higher Education System', supplement to CBI 'Education and Training Bulletin', Vol.6 No.2, Confederation of British Industry, May 1976.

[3] Some radical innovations with this aim are described in M.G.Cornwall, 'Authority v. experience in higher education : project orientation in some continental universities', Universities Quarterly, Summer 1975, pp 272 - 297.

It is very common for students to make little use of text books (see, for example, the low usage in the first year course, P.71) and depend solely on lecture notes for their source of information, both for problem solving as the course progresses and especially in revision for examinations. Their lecture notes are rarely reinforced or supplemented by additions from textbooks. Textbooks are apparently used more as a last resort in problem solving than as a medium for initial learning. Indeed, it is not uncommon in engineering for no textbooks to be recommended as immediate support for the course. Sometimes, in advanced courses, this is because none is available.

The lecture plus tutorial environment reinforces the covert message that the lecturer is the expert and font of all knowledge and that students must refer to him when they have problems.

Students are not used to using textbooks (see for example P.71). In one case, a final year production engineering class had been conducted using a teaching method based on the use of individual learning materials instead of lectures. The course evaluation conducted by the lecturer concerned showed that one of the greatest difficulties that students experienced was in reading the text which was indicated as essential reading. Indeed, some students tried to study the materials and pass the regular tests without reading the textbook - an impossible task, but one that they took some weeks to realise was so. By the time they had reached the final year these students had established the habit that all they required to do was to listen to lectures and take notes without reading books. When the lectures were removed it took them some time to adapt to the new situation. Even by the end of the course the students were finding the discipline of using textbooks an onerous one.

Aims and coverage of the curriculum

The course design strategy for the Strathclyde first year course was discussed in Part II and the non-use of an aims-centred approach to course planning was pointed out in Part I. Although staff were able to articulate some of their aims for the undergraduate course they have not engaged in this exercise in an explicit and systematic manner. Course changes are normally a result of making amendments to the existing curriculum. Whilst a highly subject-centred course exists then changes will occur in response to changes in what the staff responsible think desirable to teach. An exception to this are the Engineer in Industry and Society courses which exist in their present form by virtue of the requirements externally provided by the Institution of Mechanical Engineers. Most of the undergraduate course is organised, particularly in later years, around subjects in which staff have especial proficiency and interest. It is assumed that when these courses are assembled they will provide a balanced course for the prospective engineer.

No attempt has been made, either at Strathclyde or Heriot-Watt, to analyse the requirements of graduate engineers in terms of the skills and abilities that they require for the later aspects of their professional training and their working life and to relate these to what the university can provide. This activity is not one that should be assumed by anyone outside the university : it is a central aspect of the teaching function. What is included in the curriculum must arise from the actual needs of graduate engineering students and from an analysis of what they will require - it is not sufficient to demonstrate that what is being taught is of future relevance to students. There is a whole universe of useful engineering that could be included. It needs to be demonstrated that what is included in the undergraduate course is of higher priority than other possible activities. The assigning of priorities can only effectively be made when the various alternatives are clear.

This is not a problem of what subject matter should be included or excluded, but one of which skills and abilities should the undergraduate course be attempting to develop. It is clear from the aims survey that certain skills that are regarded as important both by staff and by students are not being adequately developed. For example, skills in written and verbal communication, skills of working with other people, etc., are agreed by staff and students to be not sufficiently developed by the courses. Teaching of these is not a simple problem as present staff are competent to teach in particular areas of engineering and the areas needing development are more human than technical skills. It is unrealistc to expect additional staff to be appointed in the current economic climate, but useful provision could be made if present staff were to prepare themselves for it

Staff-student relations and the involvement of students

There is a wide difference in the degree of contact between staff and mechanical engineering students at Heriot-Watt and Strathclyde, and in the former case this has become especially marked since the move of the Heriot-Watt department to its new buildings at Riccarton. The difference is due not just to the differences in size of the mechanical engineering sections, which is considerable (see P.99). At Strathclyde, the staff offices are on the sixth floor of the James Weir Building, away from any teaching accommodation. Students have rarely any reason to venture beyond the fifth floor, except to visit members of staff. (Design staff are situated on the same, fifth, floor as the drawing offices and the contact is similarly modified. Staff and student social facilities are entirely separate and little contact outside class hours occurs.) At Riccarton, the new Heriot-Watt accommodation has been designed to facilitate staff-student interaction. The buildings have only three floors and departments, staff rooms, teaching areas and communal social areas, are all close to each other. In the Mechanical Engineering Department an open carpeted area adjoins the lecture rooms and there are comfortable chairs in which to sit. In the mornings coffee is available and staff and students can mix freely.

At the more formal level, both universities have staff-student committees. At Heriot-Watt there is a Mechanical Engineering staff-student committee which meets regularly and discusses many issues raised by the active student body in the department. At Strathclyde, there is a committee for the School of Mechanical and Chemical Engineering and Naval Architecture covering five undergraduate degree courses. It has not met in the last two years and the students have not elected their representatives to it, despite continual encouragement by staff.

The activities of the departments, although there is quite a difference between the two institutions, do not fully take into account that students are a vital part of the educational community. If they are allowed to become passive recipients of the courses which staff provide then many opportunities are lost for the development of inter-personal and decision-making skills which are recognised as an important part of the university experience. If students are not involved in some way in planning and decision-making then their dependency on staff will be reinforced.

Course and Staff Development

Course development

University courses tend to grow by accretion, in what Hamilton has called the 'deep seated British tradition of gradualist piecemeal reform'.[1] It is seldom, if ever, possible to make a radical change in an existing course unless external pressures force such a change. Common pressures are often a severe reduction in student intake, or substantial graduate unemployment in the field of the course. When these or similar pressures are absent then it can be difficult for agreement to be reached amongst staff that a change needs to be made.

New subject matter edges out old in the active subjects, whilst in others the course can stagnate. If staff are not actively aware of alternative subject matter and alternative approaches then they will be in danger of this latter process unless circumstances force them to do otherwise. Ways of keeping actively involved in the subject are many : through reading books and journals, from attending meetings and conferences, through research, etc. It is not easy to keep in touch with teaching developments, however, as the same network of contacts, journals and exchange of information occurs to a much lesser extent in the field of teaching. The two meetings in February and June 1976 on Developing Mechanical Engineering Education, arranged by the project, were good examples of an interchange of ideas on teaching, but these are not common.

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[1] D. Hamilton, 'Curriculum Evaluation', London, Open Books, 1976.

Planned change

No effective mechanism appears to exist for forward planning at the departmental level in either institution. Although at Strathclyde each department has an Academic Plan for the future, this is more concerned with manpower and resource planning than with the detailed nature of the courses. Much of the current change policy is in response to immediate pressing problems that had been foreseen by some staff but had been rejected in terms of a collective, structured approach to dealing with them. To some staff it appears that the departments are not collectively concerned with the future.

Staff training

In the current financial situation staff mobility is low and funds that were available in the past to enable staff to visit other institutions to gain wider experience are in short supply. Such circumstances make it even more important that the development of staff is a matter of active concern.

It has already been pointed out that the number of staff within any department who are familiar with a wide range of teaching methods sufficient to make choices about the most effective ones to be deployed in any given context is quite small. Moreover, very few appear to be aware of the wide range of alternative activities that could take place even within the traditional teaching methods, for example, different structures and approaches to laboratory teaching, alternatives in lecturing, etc.[1]

The early experience of the project in the attempt to specify objectives gives similar indications of the unfamiliarity of staff with such ideas as specifying aims and objectives of courses. Arguments against this activity were not put forward from a position of familiarity with the various educational arguments that are frequently used (see Part II), but from arguments of expediency. Similarly in the area of assessment techniques, the range of examining methods is very narrow and

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[1] op. cit, P.101

the close-ended, numerical type question remains a norm and the range of methods found by the Working Party on Academic Assessment at Strathclyde in 1969 has changed hardly at all.

A major and unique exception to these comments is the Learning Unit in the Civil Engineering Department at Heriot-Watt, directed by Dr. John Cowan. The Learning Unit has developed a national reputation in the field of engineering education development. Unfortunately, there has as yet been remarkably little spillage of these ideas in the Unit to the rest of the Civil Engineering Department or to other departments at Heriot-Watt. The major influence of this work has been in other institutions and in disciplines other than engineering.[1]

Engagement in educational development is normally a low status activity. Staff feel, justifiably or not, that time invested in this activity will not be rewarded to anything like the same extent as equivalent, or even less, time spent in research. Awareness of educational problems and methods of dealing with them has, however, begun to reach the junior levels of the departments through such activities as the In-service Training Course for University Teachers.

Why innovate ?

The question can be fairly put : why is there any need to innovate? Our graduates find jobs, we have good reports of them from employers, there is no obvious dissatisfaction amongst our students: so, why innovate ? I believe we need to innovate both in our courses and in our approaches to teaching because, whatever else, the future will be different from the present and many of our present solutions will not longer be applicable.

Edgar Schein has addressed himself to the problem of what kind of professionals are needed for the future.[2] He argues that in our rapidly changing society we will increasingly generate problems which the professions, as presently constituted, will be unable to handle. He distinguished three types of role that our institutions are preparing their students for in their professional lives

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[1] Some of the factors in this are likely to be explored by a current piece of research into the Learning Unit conducted by Mohammed Mostafa Mahmoud in the Centre for Research in the Educational Sciences, University of Edinburgh.

[2] Edgar H. Schein, 'Occupational Socialization in the Professions : The Case of Role Innovation', Journal of Psychiatric Research, Vol. 8, pp 521-530, 1971
Edgar H. Schein, 'Professional Education : Some New Directions', New York, McGraw-Hill, 1972

The first is the role of custodianship. This is characterised by the acceptance of the practitioner of the currently existing norms of the profession that he will enter and by the acceptance of the current levels of knowledge and skill in that profession. He is solely concerned with using the technical training he has learned at the university. The second is that of content innovation. These will be people dissatisfied with existing levels of knowledge and skill in the profession and who will innovate in terms of the content of the discipline. The third, and the one he suggests universities should be aiming to produce, is role innovation. These are people who will redefine what is legitimate engineering practice and the bounds of present expertise. They will deal not just with new problems as the content innovators did, but with problems previously regarded as outwith the present bounds of professional practice.

Most university teachers have only experienced the first and second of these roles themselves. The academics' idea of the kind of graduates they want to produce is the most powerful determinant of the undergraduate course. The custodianship expectation will limit students to knowledge of the status quo in engineering theory and practice; content innovation expectations will tend to try to develop the innovative capacities of the student in the subject and both of these can exist within the present framework of courses. The final expectation is a more radical one and demands a rethinking of the entire curriculum, an opening up of boundaries between subjects, not only in engineering, but between engineering and other subjects and it demands a new outlook on the part of staff. As Schein puts it ,

> "The kind of professional education for role innovation...... will, of course, require professors who are themselves motivated to be role innovators vis-a-vis their own teaching role. To become involved with students in project-centred education, to work in an inter-disciplinary setting, to maintain relationships with graduates, and to become interested in social problems outside the University will require a different set of attitudes on the part of the professors."

Strategies for innovation and course development

The project itself is an example of one strategy for innovation in higher education. As described in Part I, it was initiated at the higher levels of the university outside the departmental structure and was designed to work within departments. An example of the converse strategy for change occurred with the skills tutorials. They were initiated at the level of individual members of staff and implemented on a course-wide scale. In retrospect it appears that neither approach was wholely successful in obtaining the commitment of all the people necessary for effective implementation. In the case of the project,staff in departments were not wholely committed to the idea of a project that they had not been actively involved in planning and, in the case of skills tutorials, decisions about the content and structure of the first year engineering course were taken mostly by people who were not actively involved in the design and planning of skills tutorials.

These reflections suggest that it is desirable to get commitment to a particular educational innovation at all levels of decision-making and that it is desirable that people at all levels have been actively involved in drawing up the plans, for it is in this way that an investment can be made and expectations be aroused of success.

Support for innovation

The final reflection that will be made concerns the notion of providing support for innovation, particularly in teaching. The climate within universities for innovations in teaching, if not hostile, is at least lukewarm. Those members of staff who have made substantial changes in their own teaching methods have done so at the expense of much effort, including the persuasion of colleagues to let them pursue it. One of the most valuable roles that the project has been able to provide has been that of giving support to some of these innovations. By support I refer to sympathetic, but critical, interest in the activity. It is my experience that what is needed most in educational development is not only ideas and evaluation but a supportive climate in which new activities can take root without premature judgement of their effectiveness.

Whatever else is needed in future educational developments in the two universities, the notion of support is crucial. The detailed forms that this should take is a matter for extensive discussion, but the need for people to fulfil this function has been demonstrated by the present project.

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[1] The notion of supportive evaluation has been explored in a report to the Nuffield Foundation : D. J. Boud, 'An Investigation of Course Evaluation Methods in Higher Education', Institute for Educational Technology, University of Surrey, 1975.

RECOMMENDATIONS AND PROPOSALS FOR FURTHER WORK

Some of the issues that I perceived to be of importance have been discussed. In order to provide some positive suggestions on these I have composed some proposals for future action, based on my personal judgement. These are written in the form of recommendations for sake of clarity, but they are offered by way of specific ideas for development. They have the nature of hypotheses which I regard as worthwhile to consider.

Most of the suggestions are directed towards mechanical engineering departments, although some have implications for university-wide developments. The main audience for these is in the departments in the University of Strathclyde where most recent study has been made. Some of the suggestions can also be applied at Heriot-Watt but they should be treated cautiously, as the detailed context differs and specific suggested procedures would need to be modified accordingly.

Responsibility of University Departments in Professional Education

1. Engineering departments should consider attempting to define and clarify the boundaries of their responsibility with regard to the professional training of engineers in lieu of any national decision on this matter.

Role of Practical Training in Engineering

2. Engineering departments should consider examining and making explicit the demands that they would ideally and realistically make with regard to practical training for engineering students, before, during and after the period of the undergraduate course.

Structure and Organisation of the Undergraduate Course

3. Given the present departmental structure, departments contributing to an undergraduate course should consider structuring their teaching responsibility such that the course is planned and supervised as a single unit, rather than an assembly of sub-units.

3.1 The day to day responsibility for the course to lie with a course co-ordinator drawn from the staff of the department, who should be a person of high status and with particular interest and ability in undergraduate teaching.

3.2 The course co-ordinator to be supported by year co-ordinators who would be responsible for each year of the undergraduate course and have appropriate administrative and secretarial support.

3.3 The course and year co-ordinators would form a course team who would be responsible for overseeing the undergraduate curriculum and monitoring the progress of the course. They would have direct access to the School Board and be responsible for planning and implementing changes in the course in conjunction with the heads of participating departments and their staff. The course team members would be drawn from the participating departments, but their principal teaching and administrative load would be directed towards the undergraduate course.

3.4 The course team to be seen as a co-ordinating body. Course development should not be a centralised procedure. It must actively involve all contributing staff at all stages. A consultative procedure would not encourage a sufficient investment or commitment on the part of staff.

Teaching Methods

4. Consideration should be made of the introduction of teaching methods in undergraduate courses which encourage students' autonomy. Such methods could include : individual learning materials, small-group work, greater use of textbooks and library facilities, case studies, and small scale project work.

Development of Communication Skills

5. More opportunities for the development of written and verbal communications skills should be considered for inclusion in the undergraduate course. Wherever possible this should be an integral part of engineering subjects and should not solely be developed in courses such as the Engineer in Industry and Society and special courses in communications. The effective development of these abilities requires both practice and feedback, and opportunities should be provided for both.

Assessment

6. Consideration should be made of broadening the range of aspects of courses that are assessed within the limits of the present syllabuses. This should be done to emphasise the importance of such skills as problem formulation and model building, as well as those of analysis.

Staff-student Relations

7. In the long term staff-student relations can only be developed through greater participation and involvement of students in the courses and in course development and evaluation. Social activities are worthwhile, but are not a substitute for close contact in the teaching situation. In an unsuitable physical environment, such as the James Weir Building at the University of Strathclyde, particular attempts to develop contact between staff and students should be considered.

Staff Development

8. It should be considered that staff be encouraged to broaden their interests in terms of teaching and in the social and industrial applications of the subjects they teach. Procedures for the low cost acquisition of experience by staff should be investigated. These could include the exchange of staff, the short term attachment of staff to institutions educational, industrial and public, for example, to observe and participate in new teaching practices. If these were undertaken for short periods then the disruption of teaching and research could be minimised and financial support could be arranged.

9. In particular it should be considered that staff be given the opportunity for attendance and participation in courses and workshops concerned with educational developments. Attendance should be given the same standing as that at research conferences. Funds should be made available for this so that research and teaching do not compete at the departmental level.

10. The reward structure of the institution should give adequate incentive to teaching ability vis-a-vis research and it must be seen to provide such an incentive.

Course Development

11. Developments in teaching can be most easily and effectively conducted when there is active support, both from the highest level in departments and elsewhere, and from the level of grass roots staff. It is desirable that any proposal for an educational development be initiated jointly between senior staff and those most actively involved so that both parties have an active investment in it.

12. The time scale of educational developments is long and a planned scheme should preferably be monitored over at least three years before a decision on its acceptance or rejection is made. This time should be spent on modifications and changes to make improvements in the light of an on-going programme of course monitoring.

13. It is desirable that support be provided for educational innovation. At one level it should be in terms of money that is available from the normal teaching budget to aid worthwhile schemes. At another level some form of personal support for innovative staff is helpful. This can be provided in part by consultants outwith the departments who are knowledgeable and skilled in a variety of teaching methods and who have the personal skills required to aid, but not dominate, individual innovations. Such a consultant,or consultants, could most effectively be attached to any central university facility to aid teaching.

Continuing Investigation

14. It is desirable that courses be monitored to examine their effectiveness and also that longer term planning be undertaken to provide for needs which are not being met by present provisions. These should be regular on-going activities and be recognised as important in departmental planning.

15. Participating departments should consider the worth of specifying aims and objectives both for the overall undergraduate course and for individual courses. Clear reasons should be given for the acceptance or rejection of this proposal. If the proposal is accepted then the advice of internal and external consultants should be sought on the methods to be adopted and the resources required for such an activity.

16. An investigation into examinations should be considered to determine the aims of the present assessment system as presently constructed and to assess the degree of congruence between those educational objectives that are tested and those that it is desirable to develop in students.

17. Any investigation that is considered should be undertaken first of all at departmental level as a pilot study, in order to determine the degree of commitment of staff to the process before external funds are sought.

APPENDIX

STUDENT APPRAISAL OF RESEARCH REPORTS

The following is an account of a simple but effective innovation in undergraduate engineering teaching. It is included as an example of the kind of idea that can be usefully shared by engineering teachers. The project started this process on a small scale and it is hoped that it might continue.

UNIVERSITY OF STRATHCLYDE
HERIOT-WATT UNIVERSITY

Educational Objectives in Applied Science

Student Appraisal of Research Reports

A brief description of an innovation in a final year engineering course developed by Dr. John Cowan.

INTRODUCTION

One of the problems of final year option courses is how to make them relevant to the actual practice of the professional engineer. At the end of these courses students will be taking places in industry and will be using the knowledge and skills that they have, hopefully, learned in the university. It is important for many reasons that students can appreciate the relationship between final year courses and the activities with which they may be later engaged.

Attempts are normally made in such courses to mention applications of the subject matter, but relatively little is done to enable the student to develop non-subject specific skills other than problem analysis. This account describes one activity which occupies a small part of a final year option course in Structural Concrete in the Civil Engineering Department at Heriot-Watt University. It is designed to give the students some experience of a skill that is of vital importance to practising engineers - the critical appraisal of research reports. It forms part of the wider Structural Concrete course whose aims are orientated towards professional practice rather than emphasising the academic discipline.

AIMS

The aim of the activity is to get students to read a recent research report in the subject area of the course and to make a critical appraisal of it. However, the activity is structured in such a way that students benefit from support and criticism of their colleagues and have an opportunity to defend their appraisal in front of a seminar group with a colleague acting as a discussant. An important aspect of this is that the activity should give confidence to students that they can operate at a professional level and show them that they can apply their education to a realistic task.

ELEMENTS OF THE APPRAISAL

Selection of Research Paper

The members of staff concerned (Dr. John Cowan and Mr. David Haldane) select a research report or reports for the class. Selection is made on the following grounds : one paper is chosen for each seminar group so that all students in a group have the same basis of knowledge : the paper should fall easily into sections, one section to be allocated to each student : it should be of a good standard, the criticism should not be trivial.

Briefing of Students

The critical appraisal of a research report is a new and unusual task for most students. Experience in this course has shown that students need and appreciate some guidance on how to go about the task of making an appraisal. Normally most of one lecture is devoted to a discussion of how to evaluate a report and the criteria that can be adopted. A one-page handout listing questions that the students should ask of any paper may be circulated.

First Draft of Appraisal

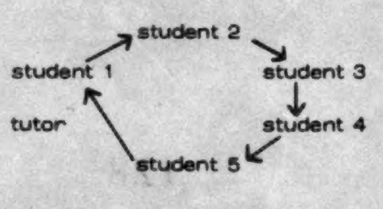
Students are each allocated a section of the paper. They write a 1½ - 4 page appreciation and critique of the section concentrating not only on the deficiencies, but also on the points that have been well expressed.

Peer Assessment of the Appraisal

The first draft of the appraisal is handed in and a photocopy is made. This copy is then given to another student (chosen at random) who has been reading the same paper. That student reads the appraisal and prepares himself to make a verbal summary and appraisal of the work of the first student in a small group seminar. No marks are given at this stage as this would be an entirely inappropriate and unhelpful act.

Small Group Seminar

A seminar is scheduled for a group of about five or six students and one member of staff. In the seminar each student gives an account of the appraisal that he has read and his critique of it. The writer of the original appraisal has a chance to defend and comment on these views and an open discussion ensues. The appraisals are allocated such that students do not both criticise and receive criticism from the same person as this might become a little acrimonious.



For example, student 1 criticises the appraisal of student 2 who, in turn, criticises the appraisal of student 3.

The role of the tutor is a very low key one : he takes part in the discussions but aims solely to facilitate the work of the students.

Revision of Appraisal

After the seminar each student has the opportunity to rewrite his original appraisal in the light of the feedback he has received. He can decide to use as much or as little of it as he sees fit. Up to this stage the appraisal has not been marked or assessed by a member of staff.

Assessment of Staff

The student hands in his final version of the appraisal. This is marked by a member of staff who was not present at the seminar and sees only the best work of the student. The standard of marking is high and work of a very high standard usually results. The appraisal is double marked by another member of staff as a check. Students can obtain up to 25 marks towards their final assessment from this task out of a total of 100 for Structural Concrete. This appraisal, then, contributes to approximately 4% of the marks for an ordinary degree and 3% for an honours degree.

Timescale

Most of the work for the appraisal takes place in the second term of the final year to avoid clashing with other major demands on the students' time. The first briefing takes place in Week 3, drafts are submitted in Week 9 and seminars take place on three afternoons in Week 10, after papers have been issued the previous Friday. Students are required to make their final submission by Week 3 in the final term.

DEMANDS ON STAFF

One of the advantages of the approach described is that it fits quite easily into the timetable. The only additional time required over the normal assessment of coursework occurs in the small group seminars. For a class of 30 students with two members of staff, a total of three seminar sessions have to be found by each tutor. These can be fitted in to laboratory periods or at other times in the afternoons.

EVALUATION

The system of research appraisals has not been subject to a thorough evaluation. However, observation of sessions and talking to staff and students concerned does indicate that they meet with great enthusiasm. Although at first students are a little anxious about assessing each other's work publicly and are wary that students who do not bother much with the first draft will have their work done for them by their colleagues, neither of these fears are serious in practice. Students do meet the challenge of expressing themselves openly and critically and students who do not put sufficient effort in the first round never seem to overtake those students who were conscientious.

I feel the scheme is of sufficient interest to circulate these brief notes in advance of any systematic evaluation that may occur at a later date.

Dave Boud

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